Appendix C
Spatial Averaging of Receptors for Toxics Risk Assessments

C.1 Summary

Air dispersion modeling for long term averages for risk assessments ~~usually feature~~typically include the single receptor ~~with~~ at the highest concentration ~~at~~ (i.e., the Point of Maximum Impact, or ~~(~~PMI), ~~at an existing residence,~~ the residential maximally exposed individual (~~R~~MEIR), ~~at an existing offsite workplace,~~ and the worker maximally exposed individual (~~W~~MEIW). Because ~~I~~individuals at a residence or a workplace ~~will~~ may tend to move around and not remain at a single point,~~. I~~it ~~therefore~~ seemed reasonable to the ARB and OEHHA to compare modeled air concentrations at a single point with the air concentrations averaged over an area where exposure might more realistically occur. Appendix C compares modeled average air concentrations of several sized averaging domains with the estimate at the PMI. It also looks at area, volume, point and line sources to determine the impact of source type and size of source on the ratio of the PMI to averaged domain. The analysis presented in this document shows how the spatial average of the collective nearby receptors can be approximately ~~65~~45% to 80% of the highest concentration depending on the source type. The spatial averaging of air concentrations at receptors is more sensitive to emissions from small sources vs. large sources. The spatial averages for nearby areas as small as (10m x 10m) up to (100m x 100m) are shown.

C.2 Introduction

Since the inception of the “Hot Spots” and the air toxics programs in California, health risk assessment (HRA) results for an individual have typically been based on air dispersion modeling results at a single point or location. This method has been traditionally used for all types of receptors (e.g., PMI, RMEI, and WMEI, pathway receptors, etc.). The assumptions used in a risk assessment are designed to preventer on the side of overestimation rather than underestimation of health impacts to the public – a health protective approach.

Air pollutant concentrations are estimated at receptors which are distributed in a grid pattern of sufficient size and density to capture the maximum concentration (e.g., at the Point of Maximum Impact (PMI)). Under some conditions, the PMI may be significantly higher than receptors only a few meters away. A more refined inhalation exposure estimate in such situations can be obtained by estimating an average concentration in a small area where the receptor might be moving about.

The Air Resources Board (ARB), in conjunction with the Office of Environmental Health Hazard Assessment (OEHHA), performed sensitivity analyses to evaluate the impacts of spatially averaging air dispersion modeling results. In this appendix, we study the sensitivity of spatially averaging the concentration of a group of receptors in the vicinity of the PMI in order to obtain an average concentration that better represents the long-term average over space and time. That information is presented below.

C.3 Source Types

Air quality modeling of facility emissions are normally carried out with a Gaussian plume model such as US-EPA's AERMOD[1]. The AERMOD algorithms include features that allow for the modeling of point, volume, and area sources. Line sources can be a special case of a series of volume or area sources.

For this analysis, we categorize each of the four source types (point, volume, area, and line) into three sizes; small, medium, and large. (Line sources are only treated as small and large.) The release parameters for input to the dispersion model are summarized in Tables 1, 2, 3, and 4. These sources are depicted schematically in Figures 1, 2, 3, and 4.

Air dispersion modeling for line sources is completed with the CAL3QHCR[2] model. CAL3QHCR is a roadway line source model. The line sources represented in this sensitivity analysis are roadway motor vehicle emissions. Roadways are not part of the Hot Spots program because the program only addresses stationary sources. However, roadways need to be modeled for proposed school sites within 500 feet of a busy roadway under SB-352. SB-352 specifies that the Hot Spots risk assessment guidance is used for the risk assessment. Differences between AERMOD and CAL3QHCR are beyond the scope of this appendix. The concepts of spatial averaging with CAL3QHCR results could be extended to AERMOD line source studies.

[1] AERMOD – A steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. U.S. EPA (2004). User's Guide for the AMS/EPA Regulatory Model - AERMOD. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC.

[2] CAL3QHCR – Line Source Model – Environmental Protection Agency, 1992. User's Guide for CAL3QHC Version 2: A Modeling Methodology for Predicting Pollutant Concentrations near Roadway Intersections. Publication No. EPA–454/R– 92–006. Office of Air Quality Planning & Standards, Research Triangle Park, NC. (NTIS No. PB 93–210250)

Figure 1 – Point Sources

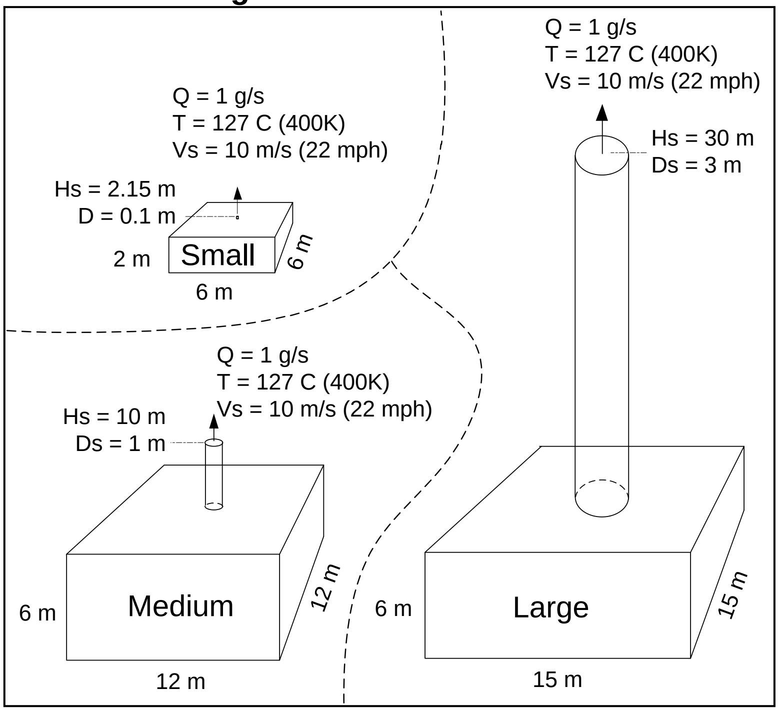


Table 1 – Point Source (Stack) Modeling Parameters

Source Size	Qs (g/s)	Hs (m)	Ds (m)	Ts[a] (K)	Vs (m/s)	FPH[b] (m)	Bh (m)	Bl (m)	Xadj Yadj (m)	Similar Sources
Large	1	30	3	400	10	370.	6	15	7.5	Power Plant / Boiler
Medium	1	10	1	400	10	97.8	6	12	6	Asphalt Batch Plant
Small	1	2.15	0.1	400	10	5.15	2	6	3	Truck Engine

a) 400 K (260 F) is at the lower end of the combustion exhaust temperature range.
b) FPH (Final Plume Height) varies with atmospheric conditions and is calculated hourly by the air quality model. For this table we calculated the FPH with US-EPA's SCREEN3 model under neutral atmospheric stability (D) and low wind speed (1m/s) for comparative purposes.

Figure 2 – Volume Sources

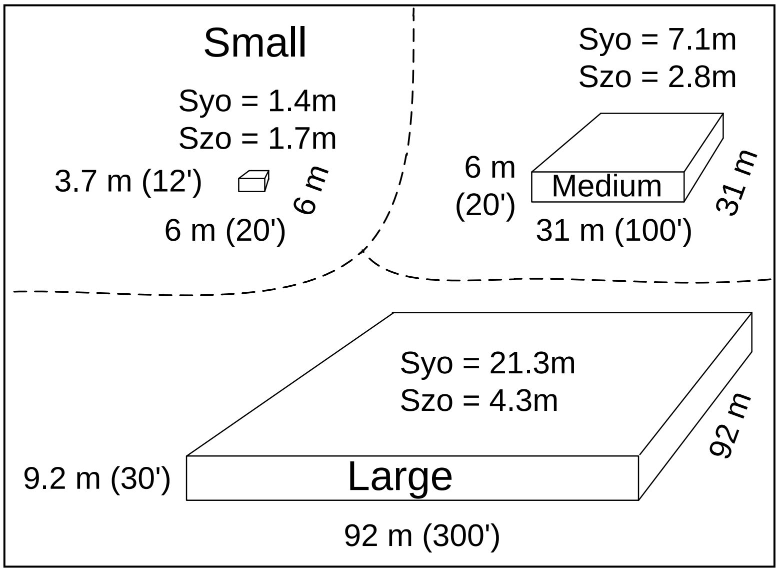


Table 2 – Volume Source Modeling Parameters					
Source Size	Qs (g/s)	Hs (m)	Syo (m)	Szo (m)	Similar Sources
Large	1	4.6	21.3 (L=92m)	4.3	Fleet Facility (300'x300'x30')
Medium	1	3.0	7.1 (L=31m)	2.8	(100'x100'x20')
Small	1	1.8	1.4 (L=6m)	1.7	Dry Cleaner (20'x20'x12')
H: Volume source height Hs: Plume centerline release height (H = 2 Hs) Syo: Initial plume dispersion in the horizontal (Syo = L / 4.3) Szo: Initial plume dispersion in the vertical (Szo = H / 2.15)					

Figure 3 – Area Sources

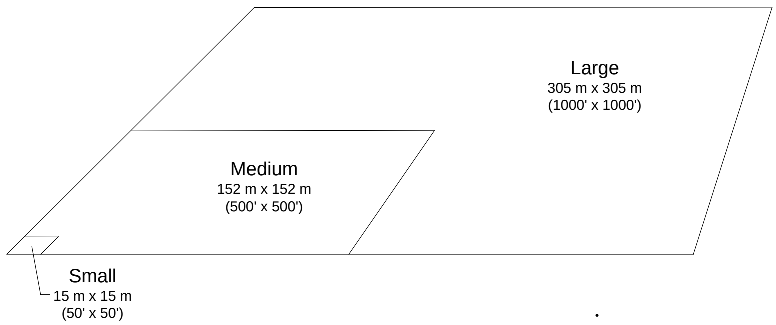


Table 3 – Area Source Modeling Parameters

Source Size	Qs (g/s)	Hs (m)	Ls (m)	Similar Sources
Large	1	3.0	305	Rail Facility (1000'x1000')
Medium	1	3.0	152	Industrial Loading Facility (500'x500')
Small	1	2.0	15	Pile (50'x50')

Figure 4 – Line Source – Large and Small

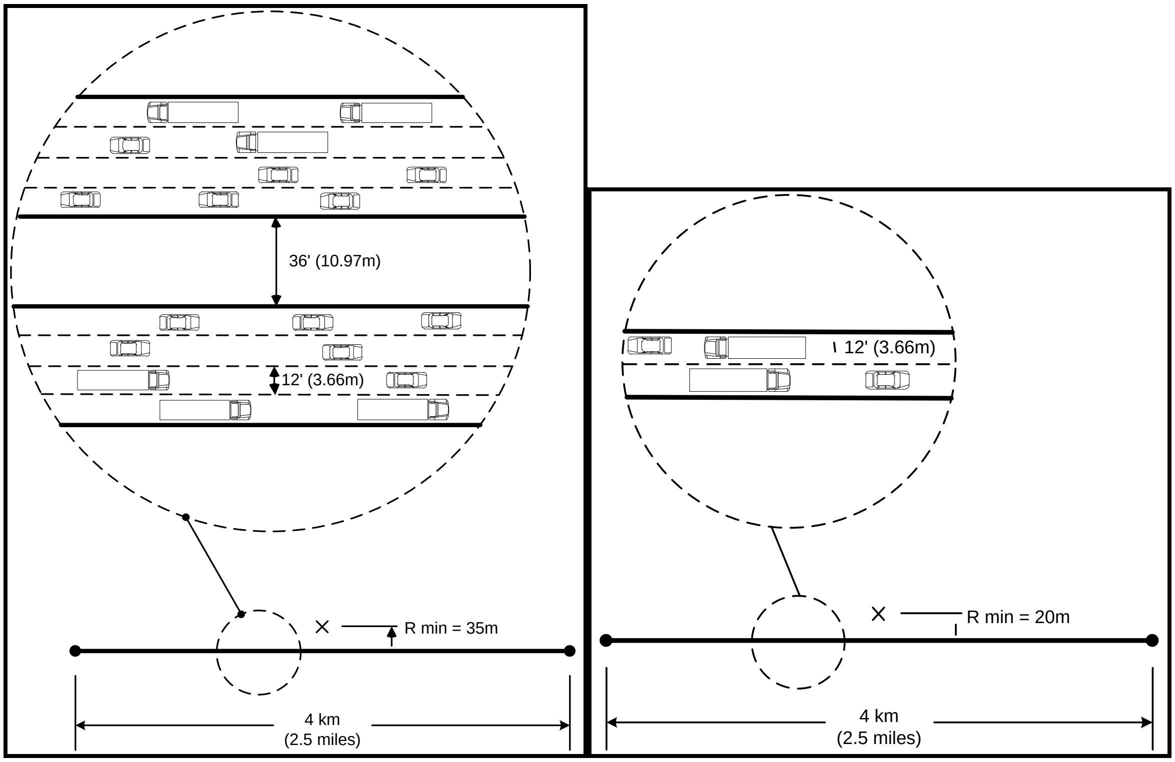


Table 4 – Line Source Modeling Parameters					
Source Size	Qs (g/s)	Vehicles per Day	Lanes	Ls (m)	Min Receptor Placement (m)
Large	1	250,000	8	4000	35
Small	1	5,000	2	4000	20

The roadway line source is simulated as four kilometers of straight roadway. The large source is an eight lane roadway where the first receptor is located 35 m from the edge of the roadway. The small source is a two lane roadway where the first receptor is located 20 meters from the edge of the roadway. Hourly variations in traffic flow are shown in the Appendix C-1.

US-EPA Guidelines[3] accept the CALINE3 and CAL3QHCR models to simulate emissions from roadways. Algorithms to simulate the enhanced mechanical turbulence and thermal buoyancy associated with motor vehicles are included in the CALINE series of models. CALINE is formulated with the Pasquill-Gifford plume distributions to simulate downwind dispersion. AERMOD is US-EPA's state-of-science dispersion model. AERMOD does not use the Pasquill-Gifford step functions of dispersion curves for estimating atmospheric stability, but rather a continuum of atmospheric dispersion is

[3] U.S. EPA (2005). Federal Register / Volume 70, Number 216 / November 9, 2005 / Rules and Regulations, 40 CFR Part 51 Appendix W, Revision to the Guideline on Air Quality Models, U.S. Environmental Protection Agency

simulated. However, AERMOD does not facilitate the hourly mechanical turbulence or thermal buoyancy associated with motor vehicles.

CAL3QHCR is used for the roadway motor vehicle emissions. Although there is potential to carefully apply AERMOD to line sources, comparing the results from these two models is beyond the scope of this sensitivity study.

C.4 Meteorological Data

AERMET is the computer program that processes and prepares meteorological data for use in AERMOD. Meteorological data that have been processed with the AERMET processor are obtained from various Districts. The latest consecutive years (up to five) were obtained. We selected the following stations for this analysis. Also see Figure 5.

- Costa Mesa (2005-2007)
- Fresno Air Terminal (FAT) (2004-2008)
- Kearny Mesa (2003-2005)
- Lynwood (2005-2007)
- San Bernardino (SBO) (2005-2007)

Figure 5 – Meteorological Station Locations

Wind rose summaries for each meteorological station are available in AppendixC- 2. The data for Costa Mesa, Lynwood, and San Bernardino are provided by the South Coast Air Quality Management District. Fresno Air Terminal (FAT) data are provided by the San Joaquin Valley Air Pollution Control District. Kearny Mesa data are provided by the San Diego Air Pollution Control District.

CAL3QHCR is a version of CALINE that can be used to simulate roadway emissions and also accepts a complete year of hourly meteorological data. CAL3QHCR requires meteorological data with Pasquill-Gifford (PG) classifications for stability. The meteorological data provided for AERMOD as discussed above do not include PG stability. Rather a continuum of stability is represented.

For the purpose of using CAL3QHCR in this sensitivity study, the PG stability class is estimated from the Monin-Obukhov length available in the AERMET processed meteorological data. As suggested by Sykes and Lewellen 1992[4], the relationship between Monin-Obukhov length and PG stability class is shown in Table 5.

Table 5 – Stability Estimates

PG Stability Class	Monin-Obukhov Length (m)
A	-5
B	-12.5
C	-50
D	-1000
E	25
F	13

As suggested by Sykes, R.I. and W.S. Lewellen (1992), "Review of potential models for UF_6 dispersion," Martin Marietta Energy Systems, Inc., Safety and Analysis Report-19 (SAR-19)

For regulatory purposes, we recommend that the stability class be determined with standard procedures for processing meteorological data with PG stability such as those available for the Industrial Source Complex – Short Term dispersion model.

The mixing height is constant at 500 meters for the CAL3QHCR simulations.

[4] Sykes, R.I. and W.S. Lewellen (1992), "Review of potential models for UF_6 dispersion," Martin Marietta Energy Systems, Inc., Safety and Analysis Report-19 (SAR-19).

C.5 Receptors

Receptors are set as flagpoles 1.2 meters above ground. A coarse receptor grid with 20 meters spacing is used to locate and center a nested grid with five meter spacing on the point of maximum impact (PMI). We selected the PMI no closer than 20 meters to a point source; 20 meters to the virtual edge of a volume source; or zero meters to the edge of an area source. AERMOD limitations on receptor placement are that no receptors be located within one meter of the point source and no receptors within a volume source. Receptors within an area source are still valid.

The nested grid was centered on the PMI for the large and medium point source receptors. For the small point source, volume sources, area sources, and line sources, the near edge of the grid was centered on the PMI in order to keep nested receptors off of the source. Simple arithmetic averaging was used to average the nested grid over the PMI with various nesting domain sizes. Figure 6 shows the PMI and two nested grids for the large point source.

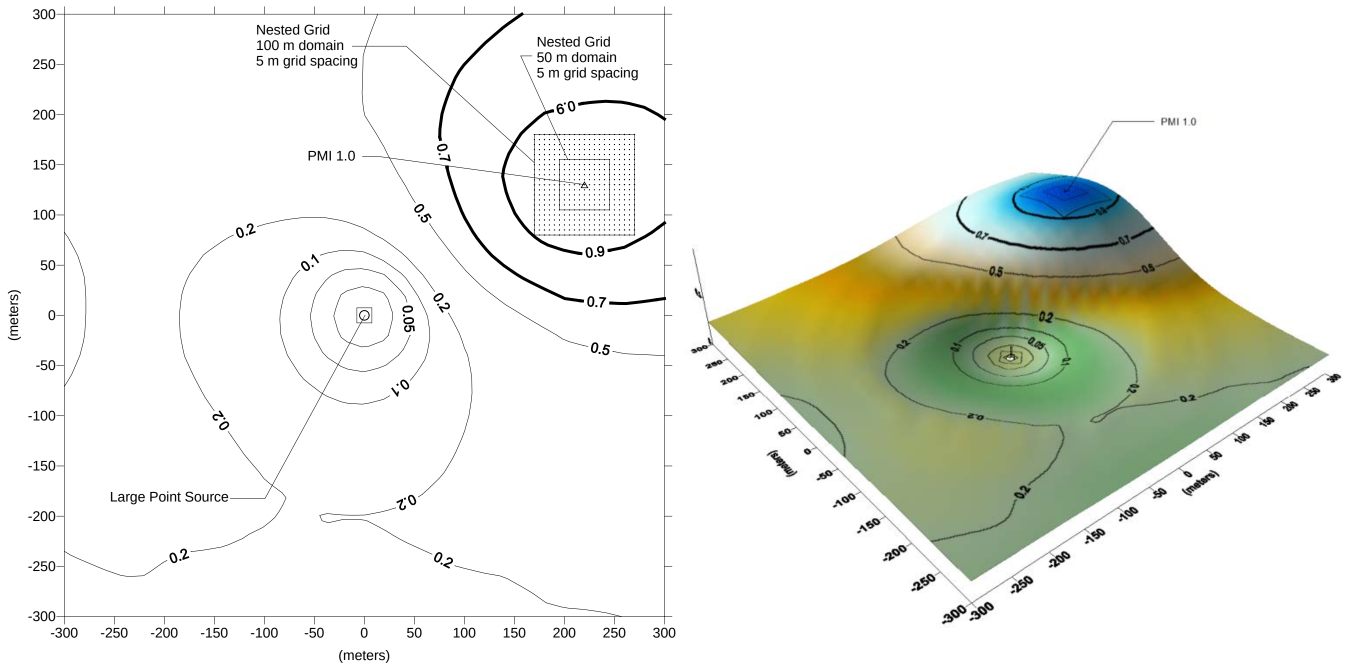
Appendix 3 shows the PMI and two nested grids for each source (point, volume, area, and line) and for all sizes.

The spatial average was calculated for nested grids at ten different domains; 10m x 10m up to 100m x 100m, even though only two nested grids are shown on each plot.

An emission rate of 1 g/s was used for each source type. The resulting concentration field output was normalized to the offsite PMI. Therefore, the offsite receptor concentrations have a maximum value of 1.00 $\mu g/m^3$.

Figure 6
Concentration Distribution (Normalized to PMI)
Large Point Source

Isopleths ***Surface***



C.6 Results

The graphical displays of the concentration fields from the multitude of source types and meteorological representation are available in Appendix 3. It is evident from these figures that estimated ground level concentrations fall off most steeply from the PMI with smaller source types with a low plume rise where the PMI is located at the property fence line. This is to say that the spatial average is lowest relative to the PMI with this type of small source. Source types with high plume rise (e.g., tall stacks in Figures AP3.1.1 – 1.5) show a PMI far downwind where the concentration gradient is more gradual and therefore the difference between the estimated air concentration with the spatial average and the PMI is less.

The results of the spatial averaging are summarized in Figures 7 – 10. Supporting tables are available in Appendix C-4.

The spatial averaging for a 10m x 10m receptor field can be as low as 65% of the PMI value as seen in Table AP4.3.3 and Figure 9.3.

In addition, the graphical displays in Appendix 3 show that the dominant plume centerline is sometimes tilted from the cardinal directions. Since the nested grids for spatial averaging were placed along the cardinal directions, the results in Appendix C- 4 may underestimate a spatial average centered on the dominate plume centerline. Appendix C-5 shows how tilting the nested grid to coincide with the dominat plume centerline can increase the value of the spatial average. The value of the spatial averaged tilted grid may be higher than the non-tilted counterpart (e.g., 0.69 vs. 0.59). Whether or not to tilt the grid is a subjective decision and should be considered on a case-by-case basis.

C.7 Recommendations

Spatial averaging may be used to estimate a long term concentration over a small nested grid of receptors to represent an area vs. a single location as determined by the Point of Maximum Impact (PMI). Spatial averaging is most applicable for the following conditions.

- Long term averages are being calculated to represent multi-year impacts.
- The Point of Maximum Impact (PMI) is located at the fence line and close to the emission source.
- The concentration gradient is high near the PMI. This is more associated with low level plumes such as fugitive, volume, or area sources.

The following are recommendations for calculating the spatial average.

1. Spatial averaging should not be used for maximum one hour air concentration estimation.
2. Locate the off-site PMI with a nested grid resolution spacing of no greater than five meters. Two or more model runs with successively finer grid resolutions centered on the new PMI may be required to locate the final PMI.
3. Center the nested grid on the off-site receptors about the PMI. Limit the nested grid to 20m x 20m. The grid resolution spacing should be no greater than five meters. With a 5m grid resolution, the 20m x 20m nest will result in 25 receptors.
4. If necessary, tilt the nested grid to coincide with the dominat plume centerline. Polar receptors are easier to implement than a tilted rectangular grid. The domain of the polar receptor field should be limited to a 15 meter polar radius.

Although this sensitivity study evaluated nested grids up to 100m x 100m, the above recommendation is to limit the nested grid domain to 20m x 20m if rectangular and a radius of 15m if polar. (A 20m x 20m square area is equivalent to a 16m radius half circle. Therefore we rounded down to 15m radius for convenience.)

As a frame of reference, low density single family detached dwellings have been described in some city municipal codes as RD4 – RD7 zoning. RD4 allows four units per acre of land and RD7 allows seven units per acre of land. Table 6 shows the equivalent acreage and size in meters of RD4 – RD7 lots assuming uniformly distributed and square lots.

Table 6 – Residential Zoning vs Lot Size

Zone	Lot Size (acres)	Lot Size Square Meter
RD4	0.250	32m x 32m
RD5	0.200	28m x 28m
RD7	0.143	24m x 24m
-	*0.099*	*20m x 20m*

Figure 7.1

Large Point Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

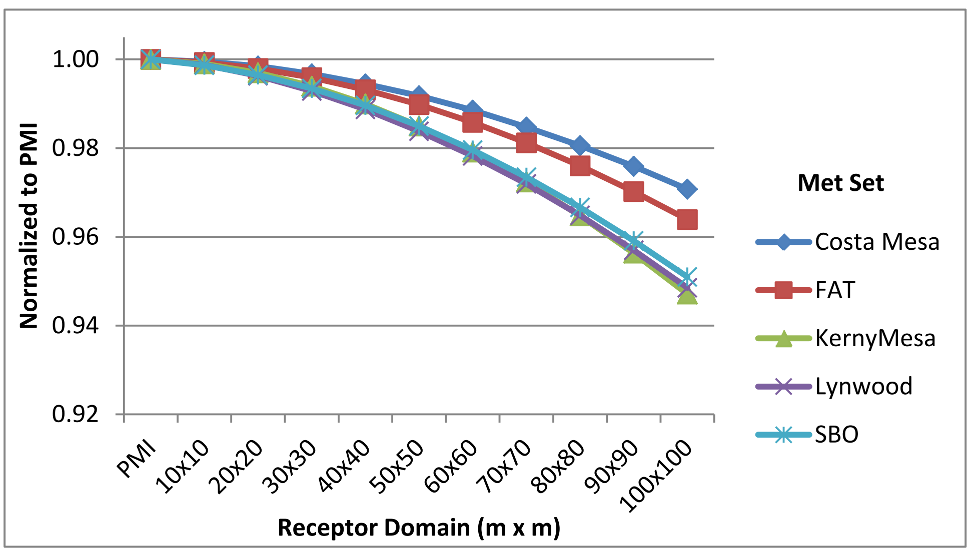


Figure 7.2

Medium Point Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

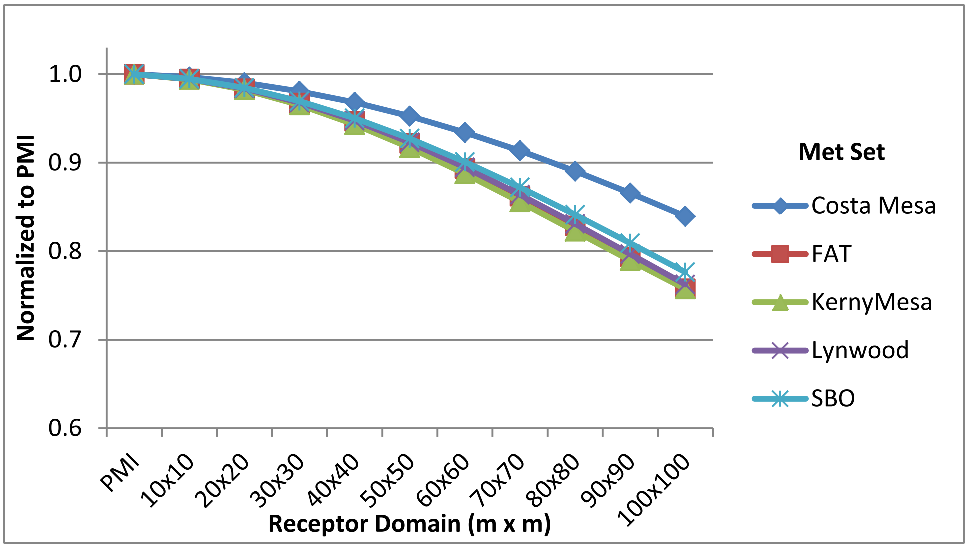


Figure 7.3

Small Point Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

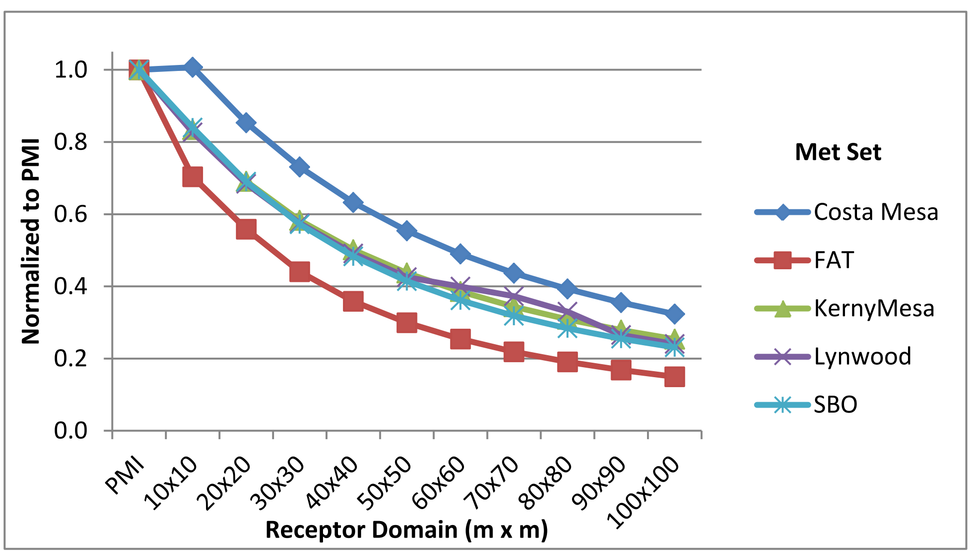


Figure 8.1
Large Volume Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

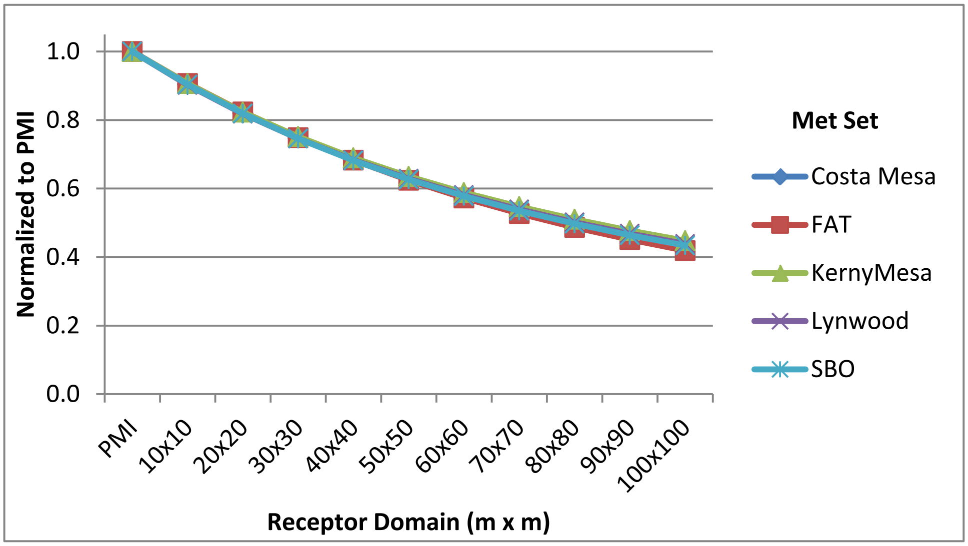


Figure 8.2
Medium Volume Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

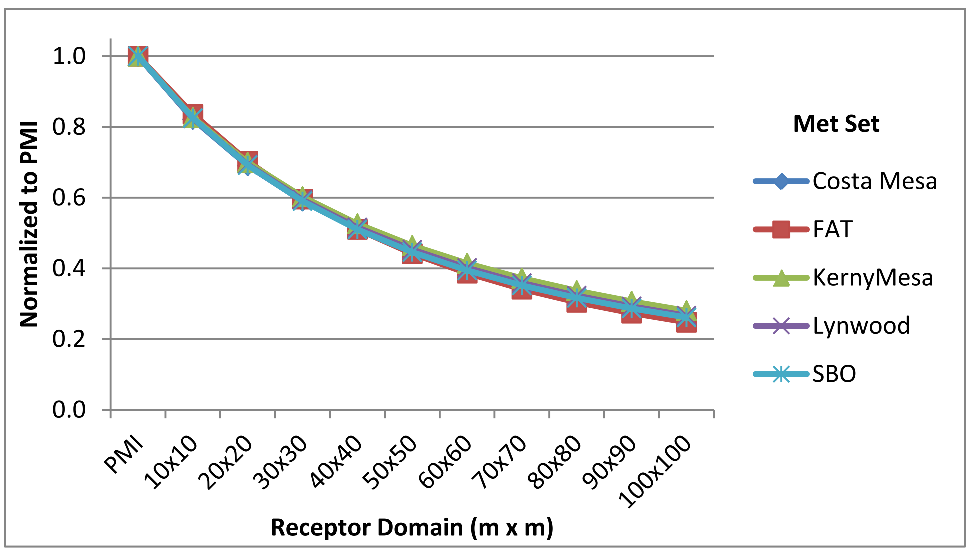


Figure 8.3

Small Volume Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

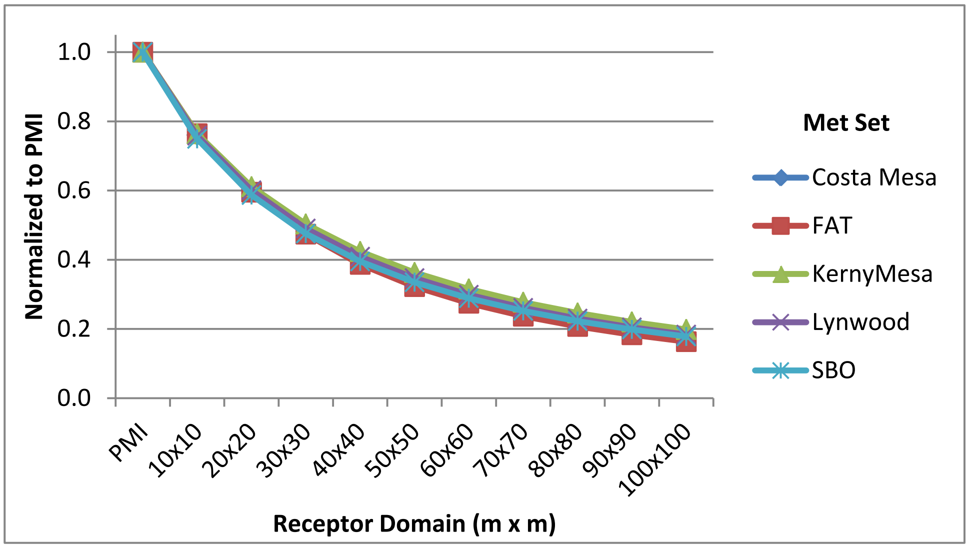


Figure 9.1

Large Area Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

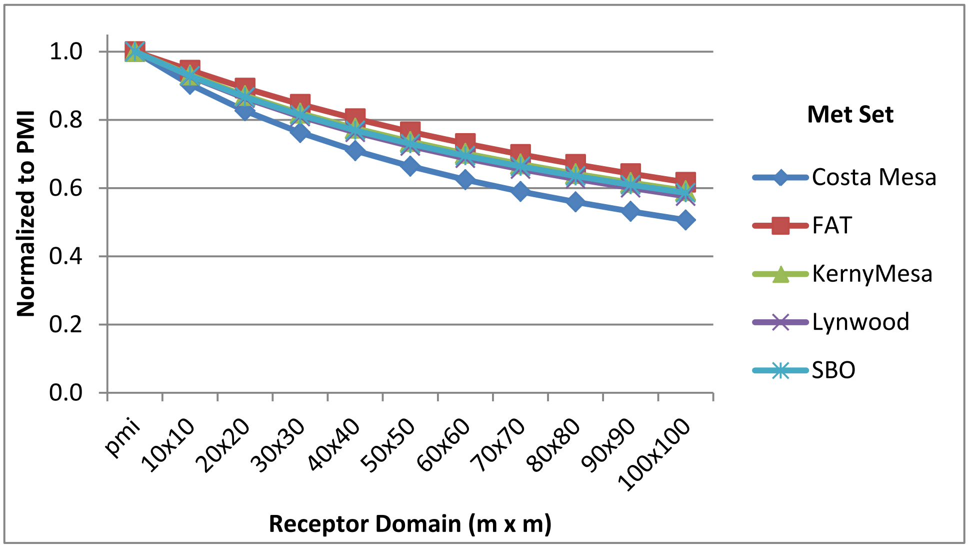


Figure 9.2
Medium Area Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

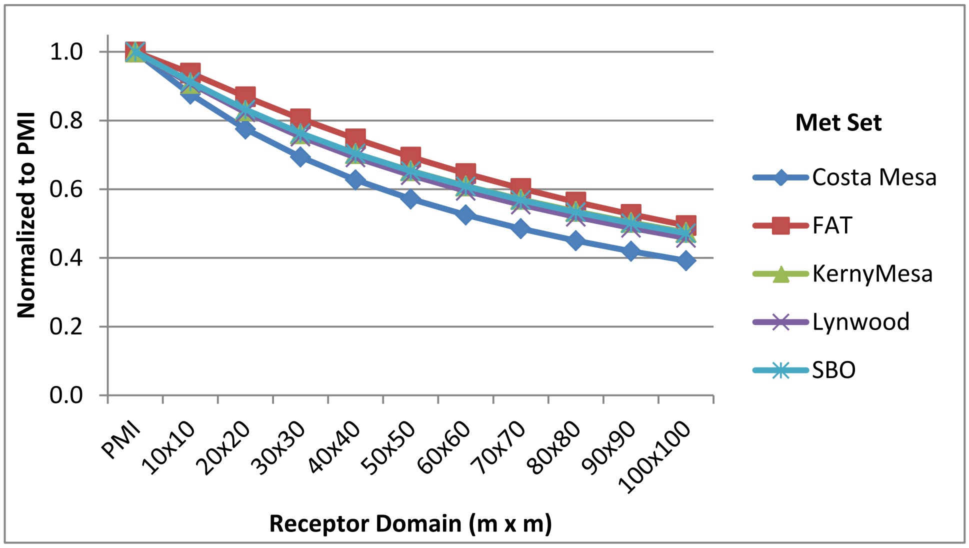


Figure 9.3
Small Area Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

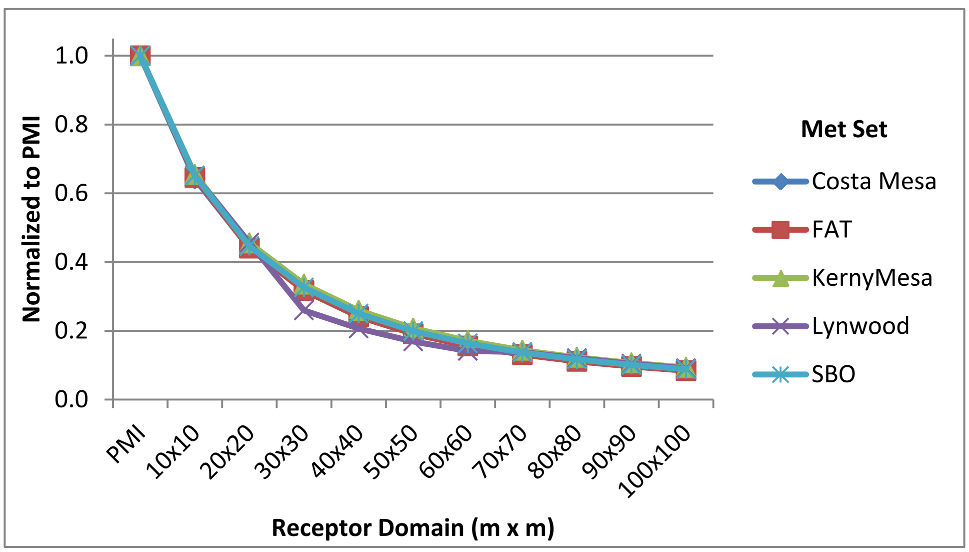


Figure 10.1
Large Line Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

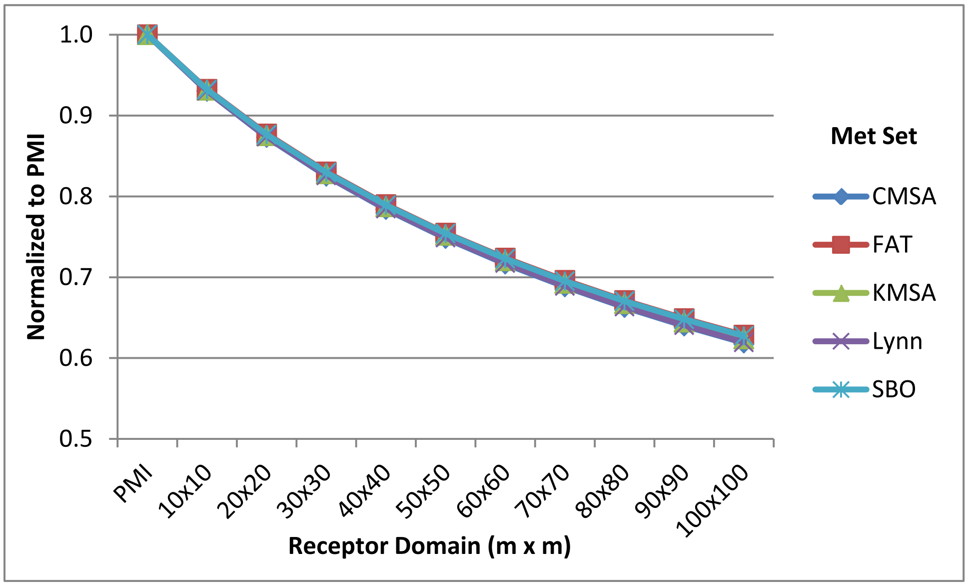
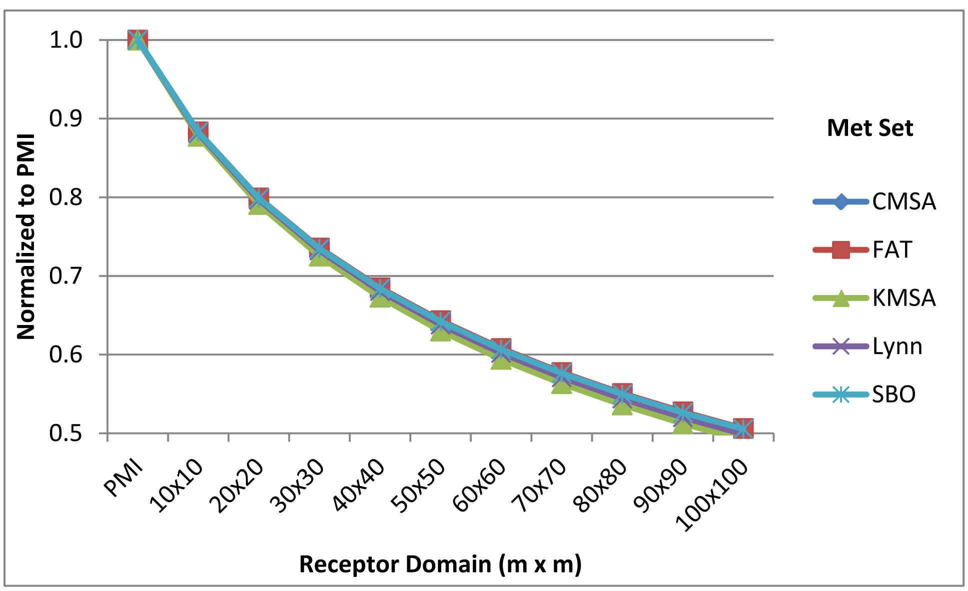


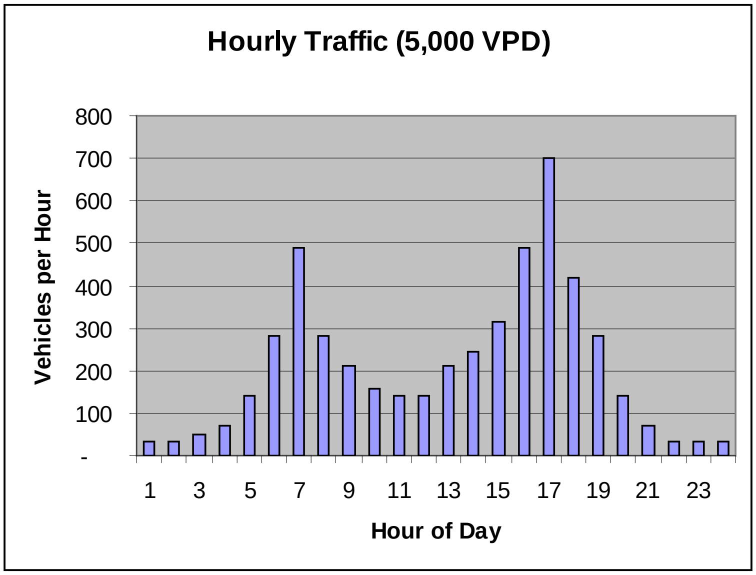
Figure 10.2
Small Line Source Spatially Averaged GLCs with Several Domain Sizes and Five Meteorological Data Sets

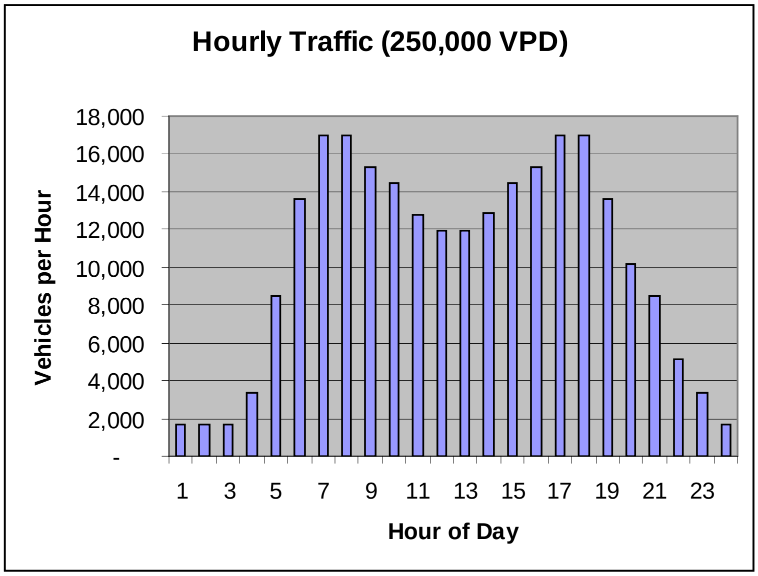
e



Appendix C-1 – Hourly Variation for Traffic Line Source

Hour	5K VPD	250K VPD
1	35	1,700
2	35	1,700
3	49	1,700
4	70	3,400
5	140	8,500
6	280	13,600
7	490	17,000
8	280	17,000
9	210	15,300
10	156	14,450
11	140	12,750
12	140	11,900
13	210	11,900
14	245	12,850
15	315	14,450
16	490	15,300
17	700	17,000
18	420	17,000
19	280	13,600
20	140	10,200
21	70	8,500
22	35	5,100
23	35	3,400
24	35	1,700
Sum	5,000	250,000
Peak Hour	700	17,000





Appendix C-2 – Meteorological Data

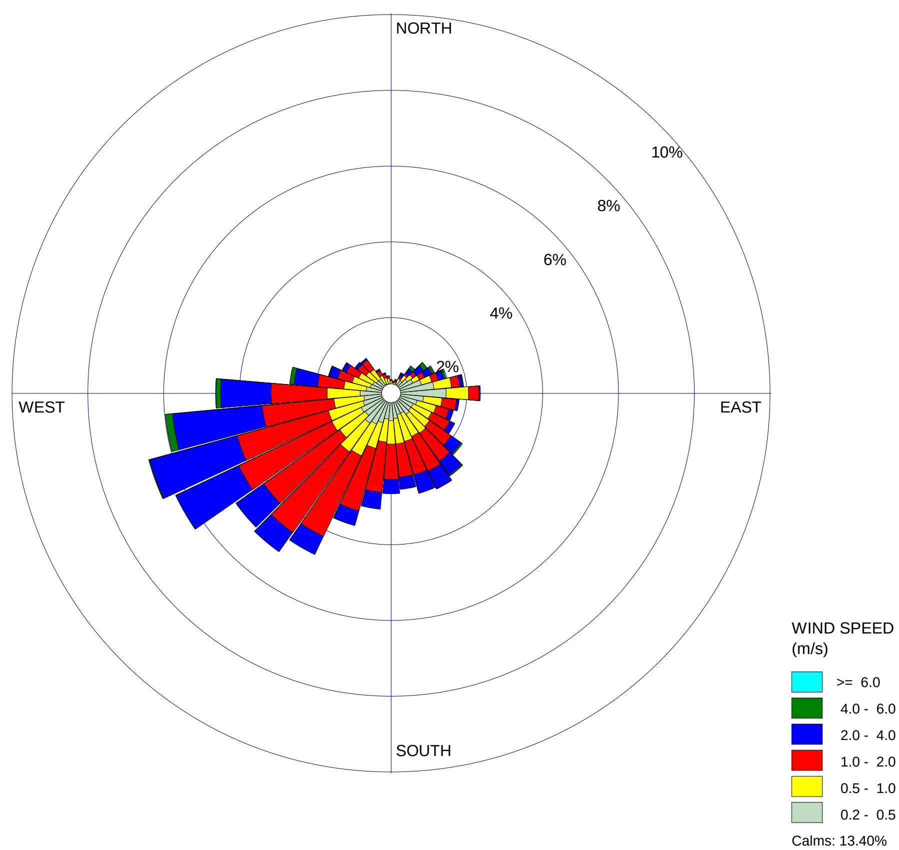
Figure ApC-2.1
AERMET Data from Districts

The above figure shows the locations where AERMET data are available from Districts. We selected the following stations for this analysis which include stations that are near the ocean and inland – Costa Mesa, Fresno Air Terminal (FAT), Kearny Mesa, Lynwood, and San Bernardino.

Figure AP C-2.2 – Costa Mesa – Wind Rose Summary

WIND ROSE PLOT:
Station #0

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
Costa Mesa
1 km/hr threshold (0.28 m/s)

DATA PERIOD:
2005-2007
Jan 1 - Dec 31
00:00 - 23:00

COMPANY NAME:

MODELER:

CALM WINDS:
13.40%

TOTAL COUNT:
25385 hrs.

AVG. WIND SPEED:
1.06 m/s

DATE:
7/6/2010

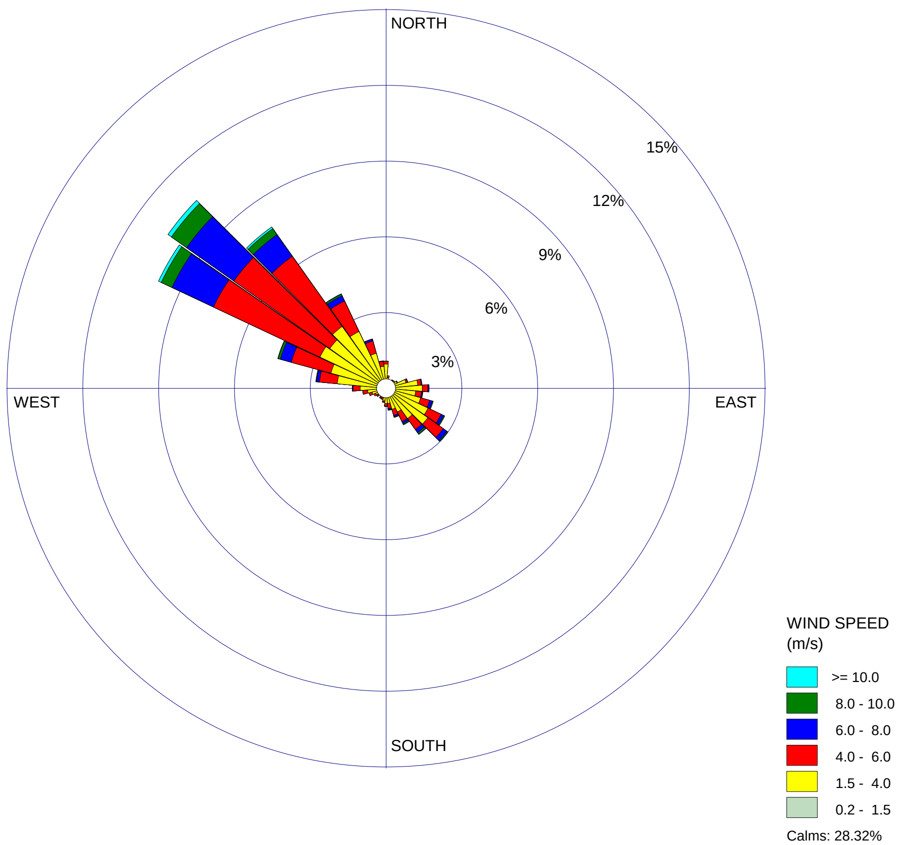
PROJECT NO.:

WRPLOT View - Lakes Environmental Software

Figure AP C-2.3 – Fresno Air Terminal – Wind Rose Summary

WIND ROSE PLOT:
Station #93193 - FRESNO/AIR TERMINAL, CA

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
FAT
3 knot threshold (1.5 m/s)

DATA PERIOD:
2004-2008
Jan 1 - Dec 31
00:00 - 23:00

COMPANY NAME:

MODELER:

CALM WINDS:
28.32%

TOTAL COUNT:
43198 hrs.

AVG. WIND SPEED:
2.79 m/s

DATE:
7/6/2010

PROJECT NO.:

WRPLOT View - Lakes Environmental Software

Figure AP C-2.4 – Kearny Mesa – Wind Rose Summary

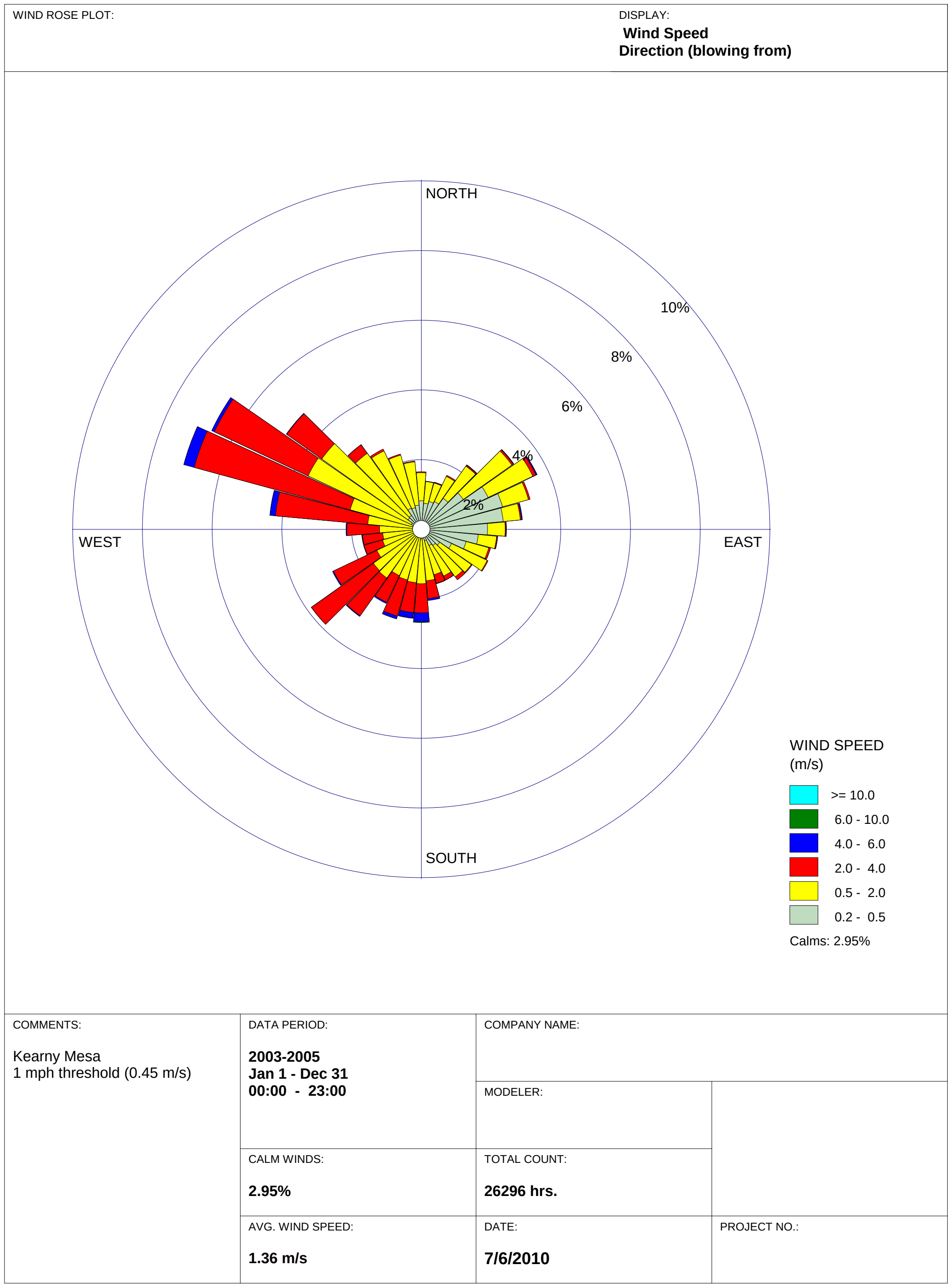
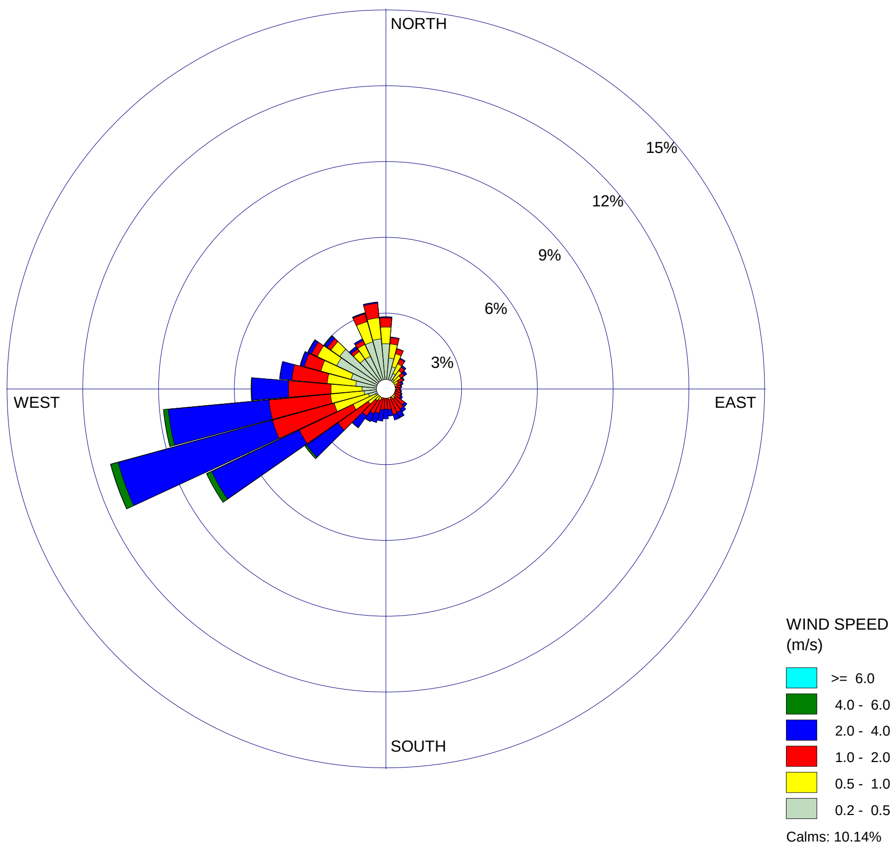


Figure AP C-2.5 – Lynwood – Wind Rose Summary

WIND ROSE PLOT:

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
Lynwood
1 km/hr threshold (0.28 m/s)

DATA PERIOD:
2005-2007
Jan 1 - Dec 31
00:00 - 23:00

COMPANY NAME:

MODELER:

CALM WINDS:
10.14%

TOTAL COUNT:
25852 hrs.

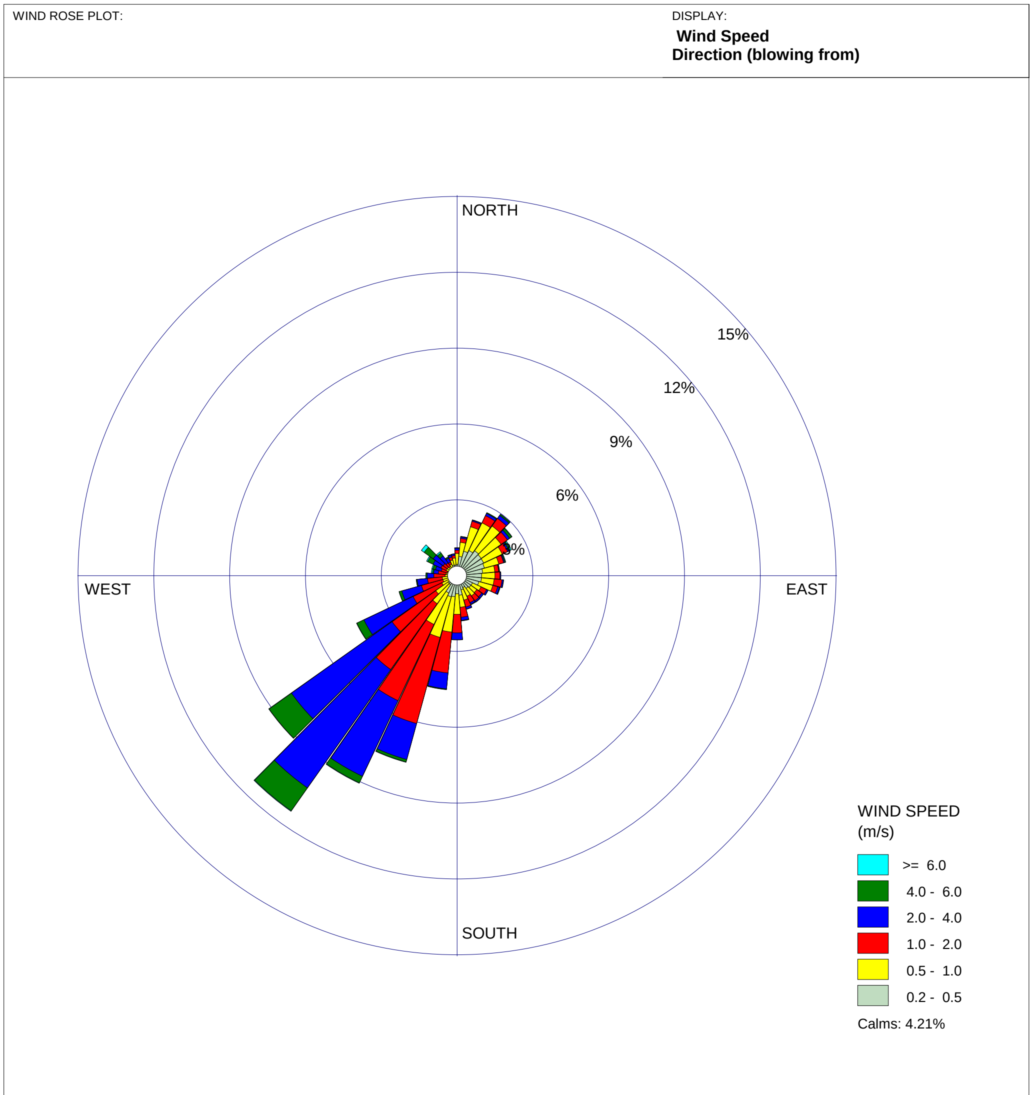
AVG. WIND SPEED:
1.16 m/s

DATE:
7/2/2010

PROJECT NO.:

WRPLOT View - Lakes Environmental Software

Figure AP C-2.6 – San Bernardino – Wind Rose Summary



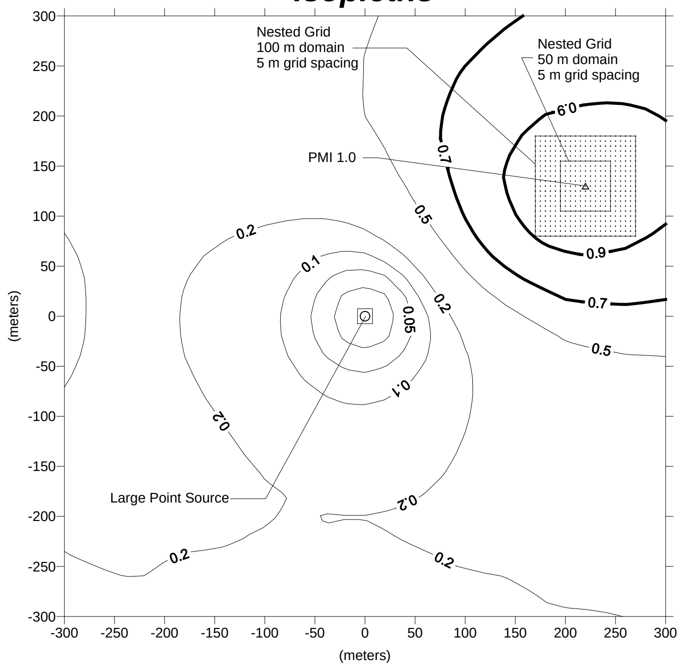
COMMENTS: San Bernadino 1 km/hr threshold (0.28 m/s)	DATA PERIOD: **2005-2007** **Jan 1 - Dec 31** **00:00 - 23:00**	COMPANY NAME:	
		MODELER:	
	CALM WINDS: **4.21%**	TOTAL COUNT: **26126 hrs.**	
	AVG. WIND SPEED: **1.44 m/s**	DATE: **7/6/2010**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

Appendix C-3 – Sources, Receptors, Concentrations

Figure AP C-3.1.1 – Large Point Source – Costa Mesa

Isopleths



Surface

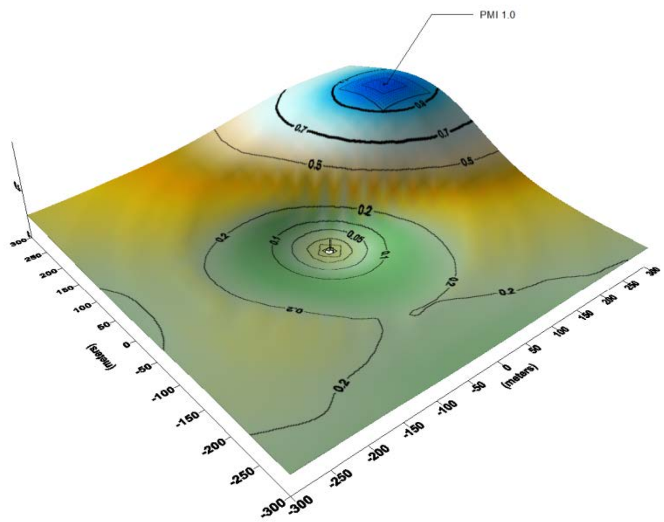
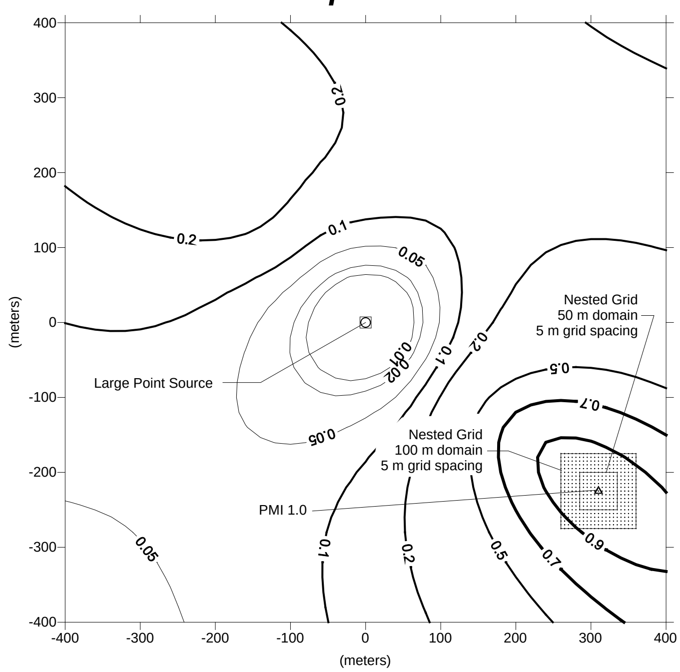


Figure AP C-3.1.2 – Large Point Source – Fresno Air Terminal

Isopleths



Surface

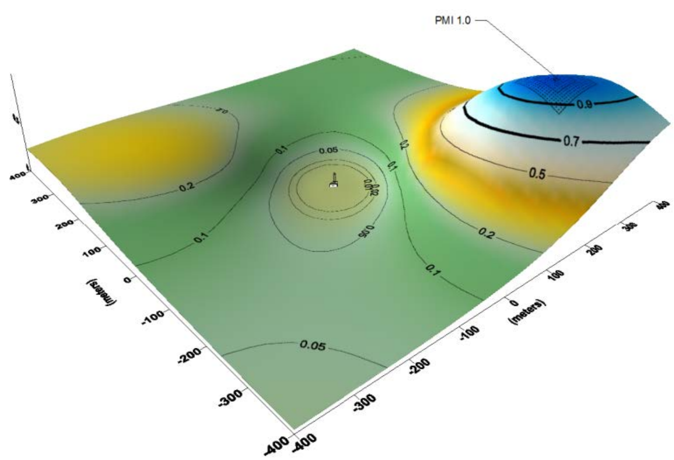


Figure AP C-3.1.3 – Large Point Source – Kearny Mesa

Isopleths ***Surface***

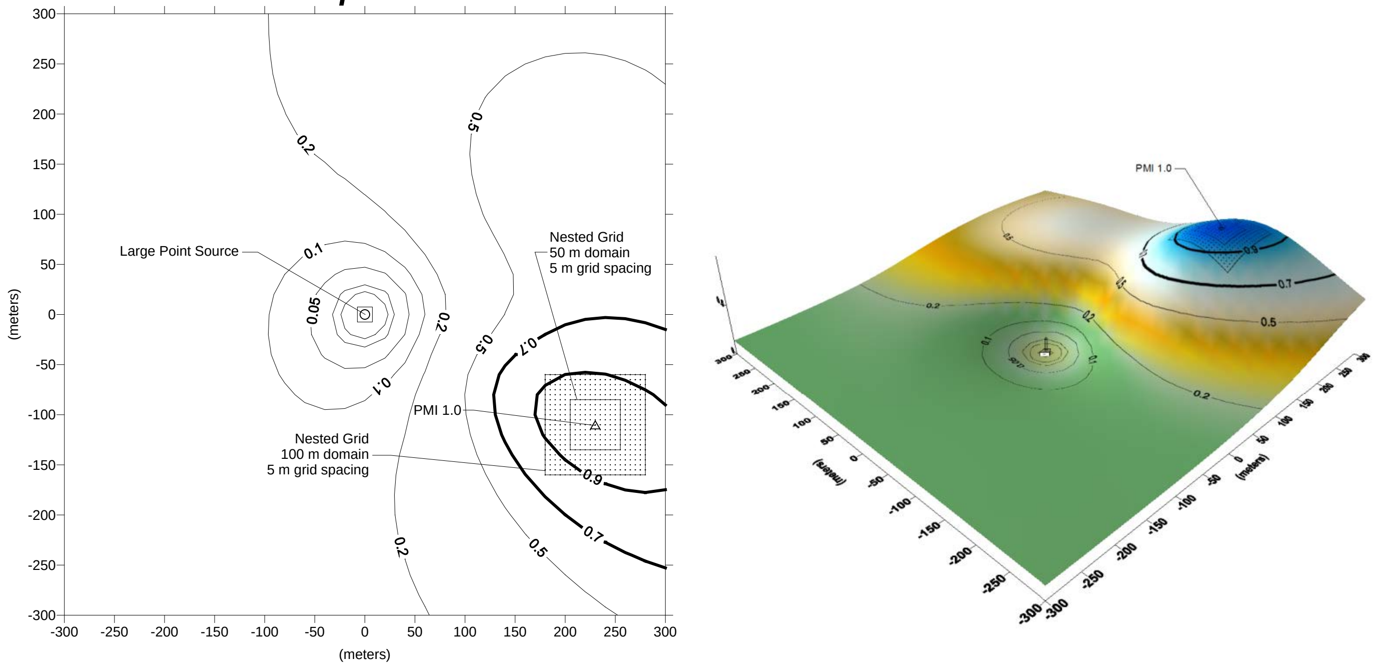


Figure AP C-3.1.4 – Large Point Source – Lynwood

Isopleths ***Surface***

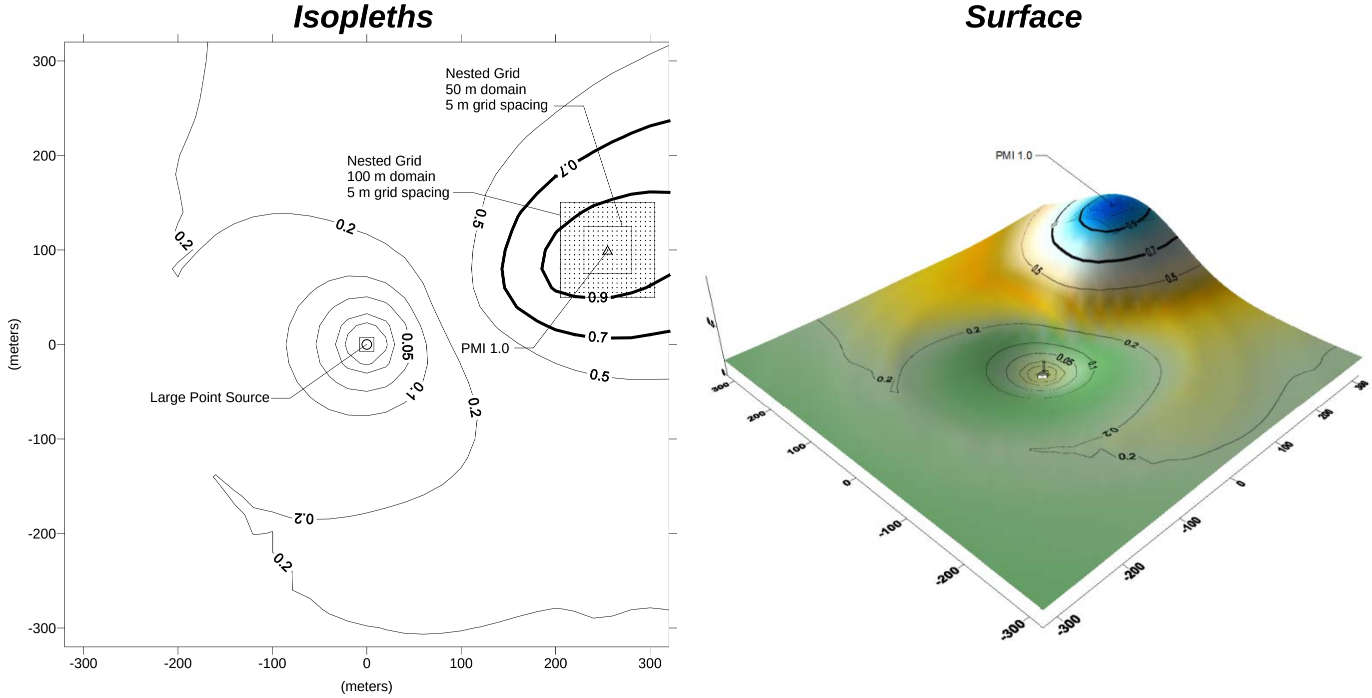


Figure AP C-3.1.5 – Large Point Source – San Bernardino

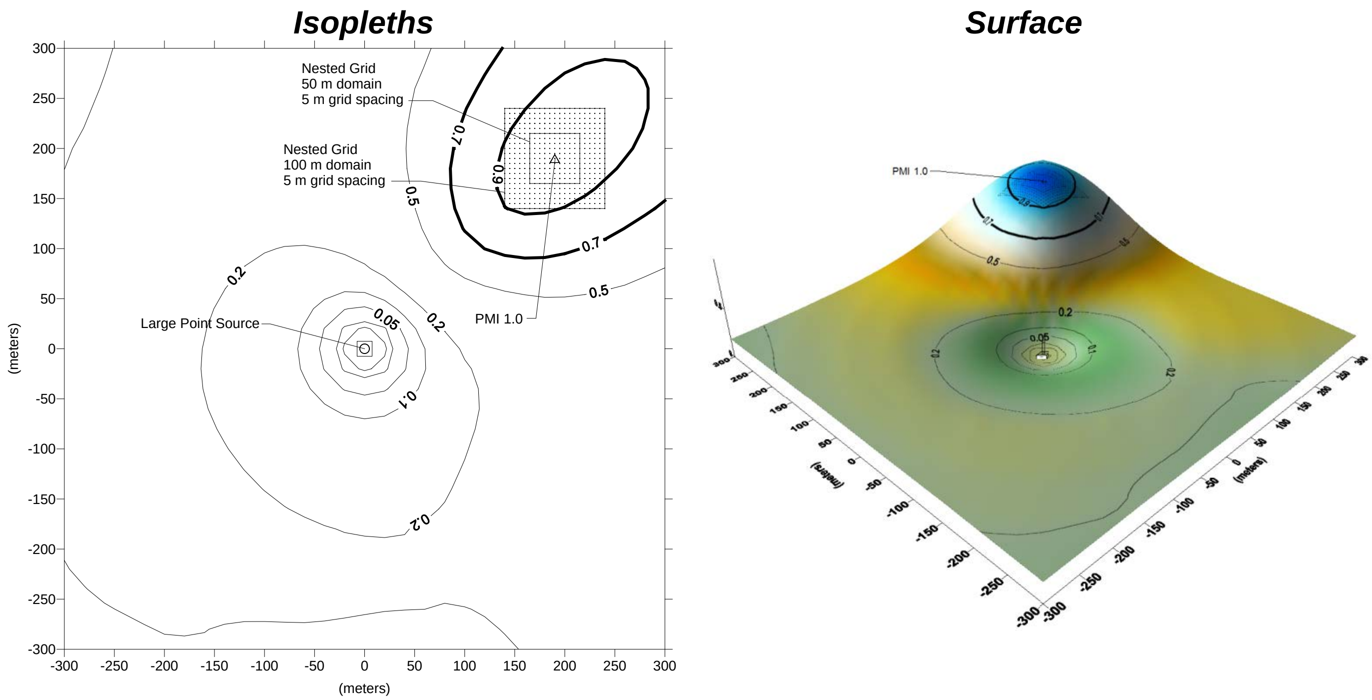


Figure AP C-3.2.1 – Medium Point Source – Costa Mesa

Isopleths ***Surface***

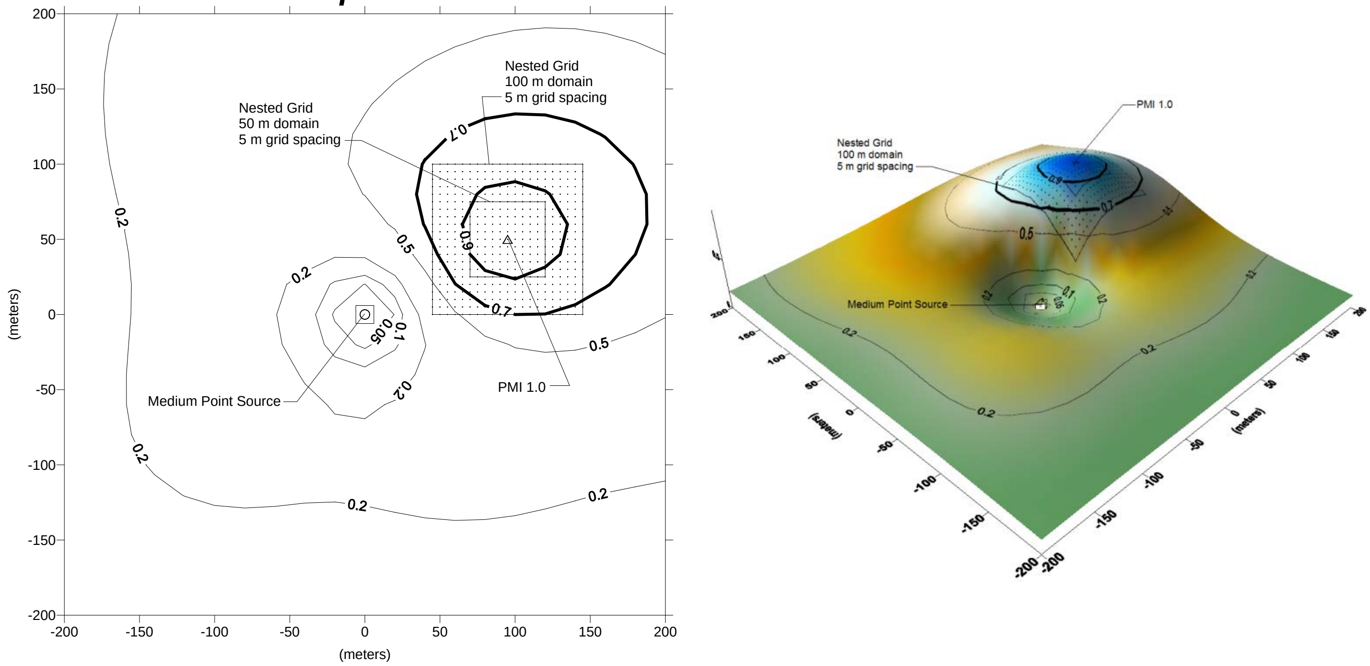


Figure AP C-3.2.2 – Medium Point Source – Fresno Air Terminal

Isopleths ***Surface***

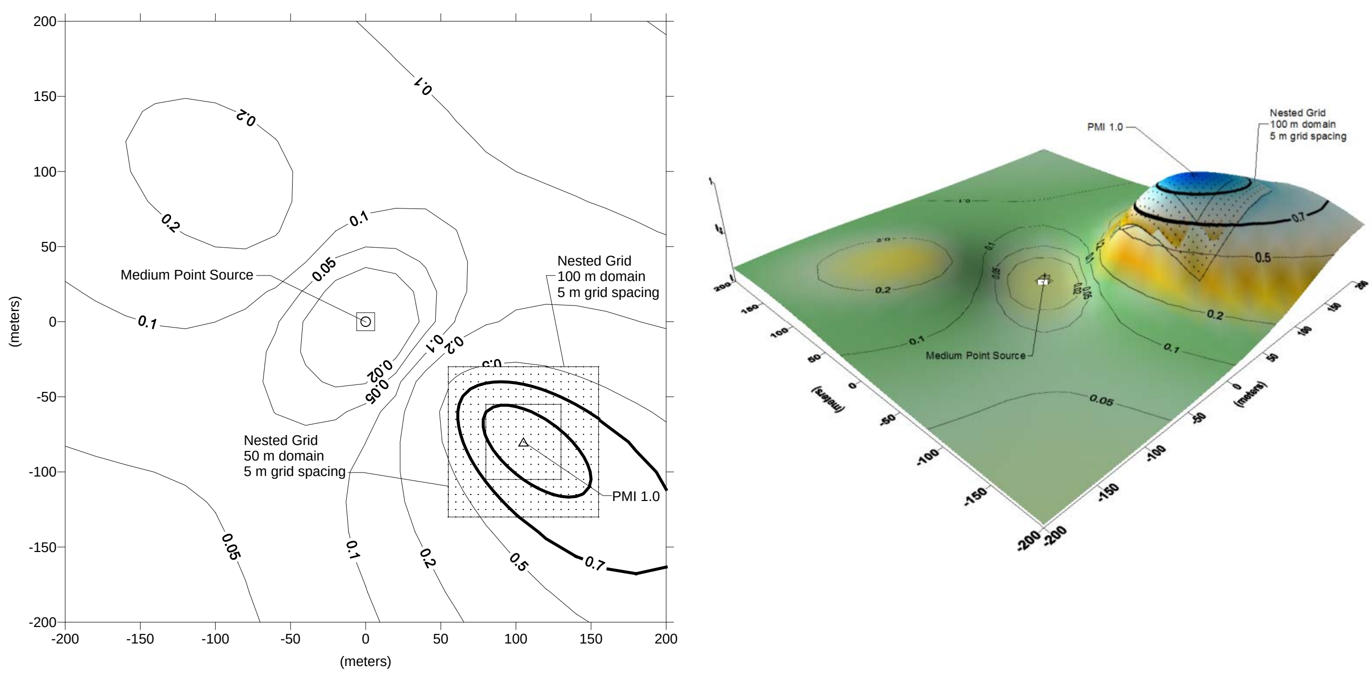
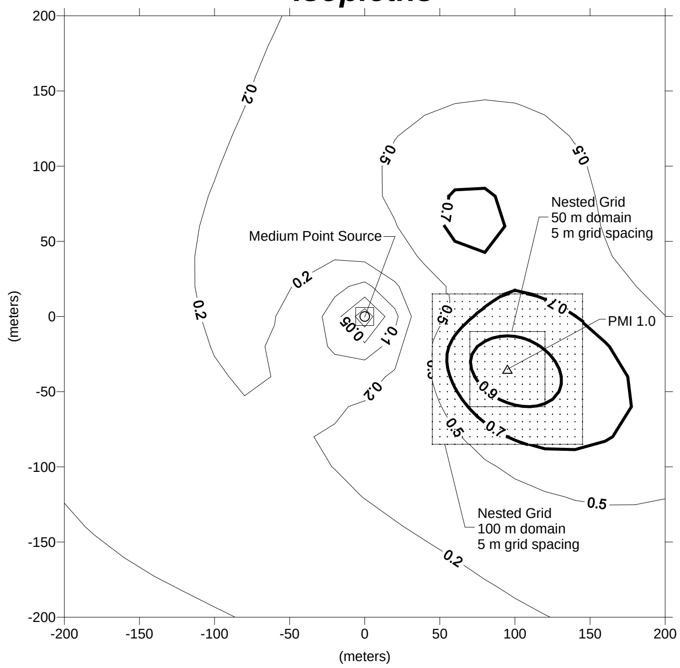


Figure AP C-3.2.3 – Medium Point Source – Kearny Mesa

Isopleths



Surface

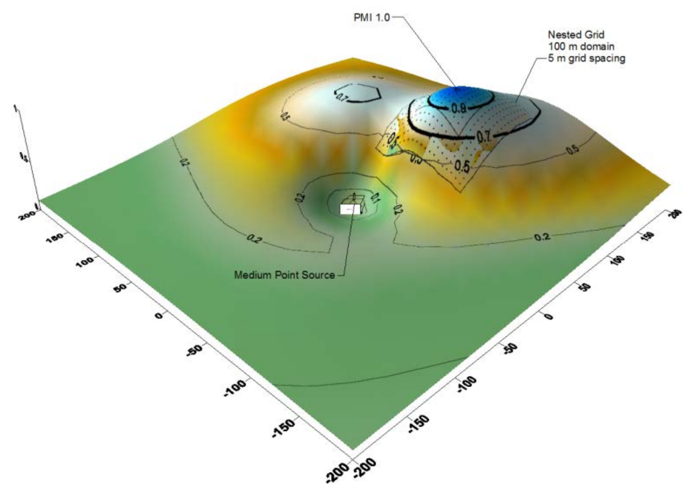
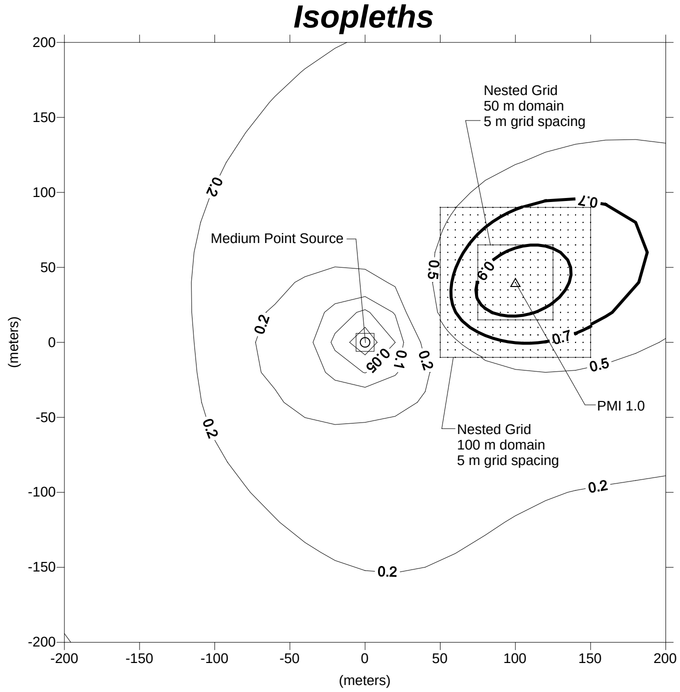


Figure AP C-3.2.4 – Medium Point Source – Lynwood

Isopleths



Surface

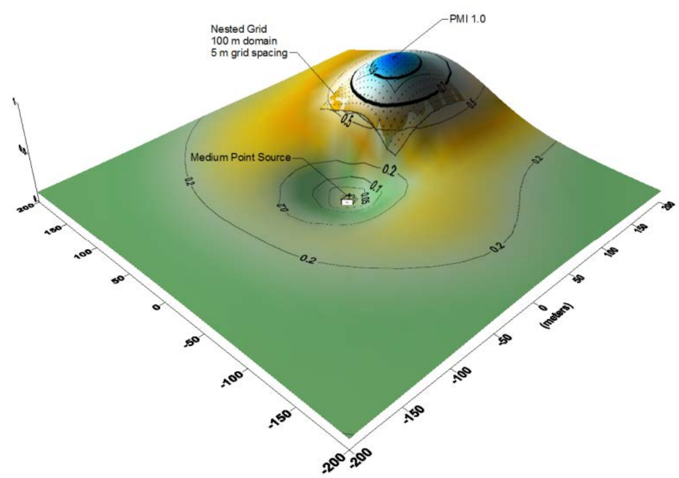
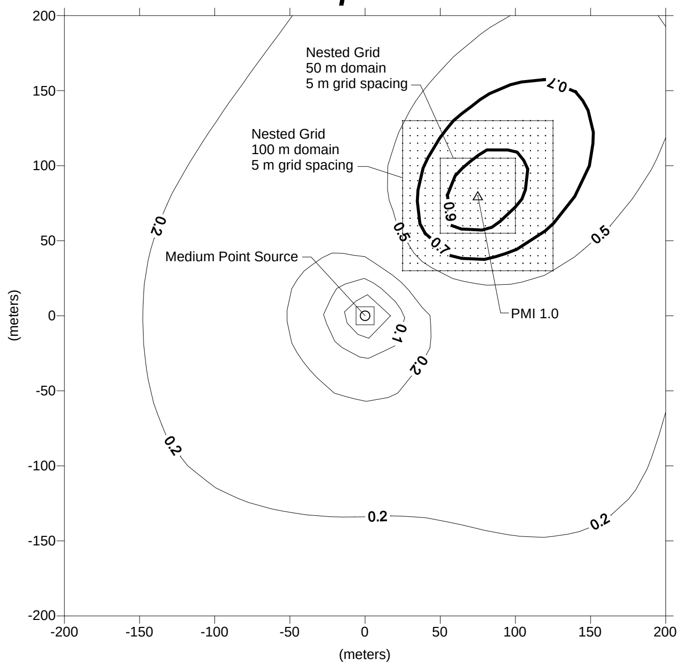


Figure AP C-3.2.5 – Medium Point Source – San Bernardino

Isopleths



Surface

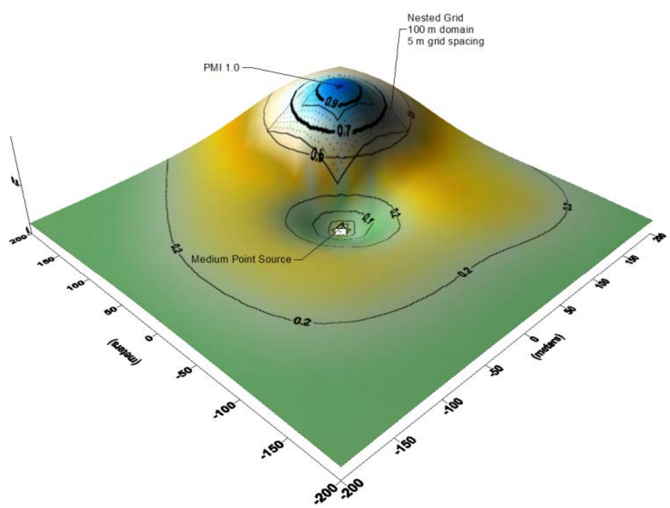


Figure AP C-3.3.1 – Small Point Source – Costa Mesa

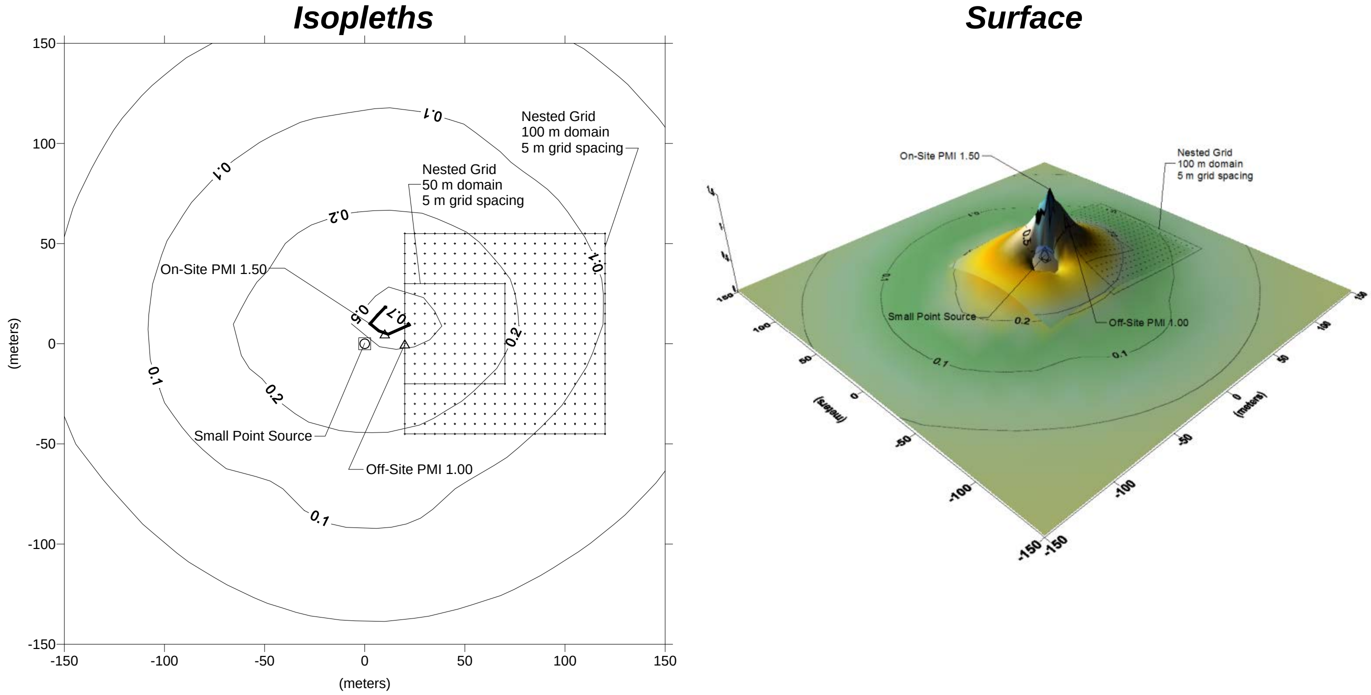


Figure AP C-3.3.2 – Small Point Source – Fresno Air Terminal

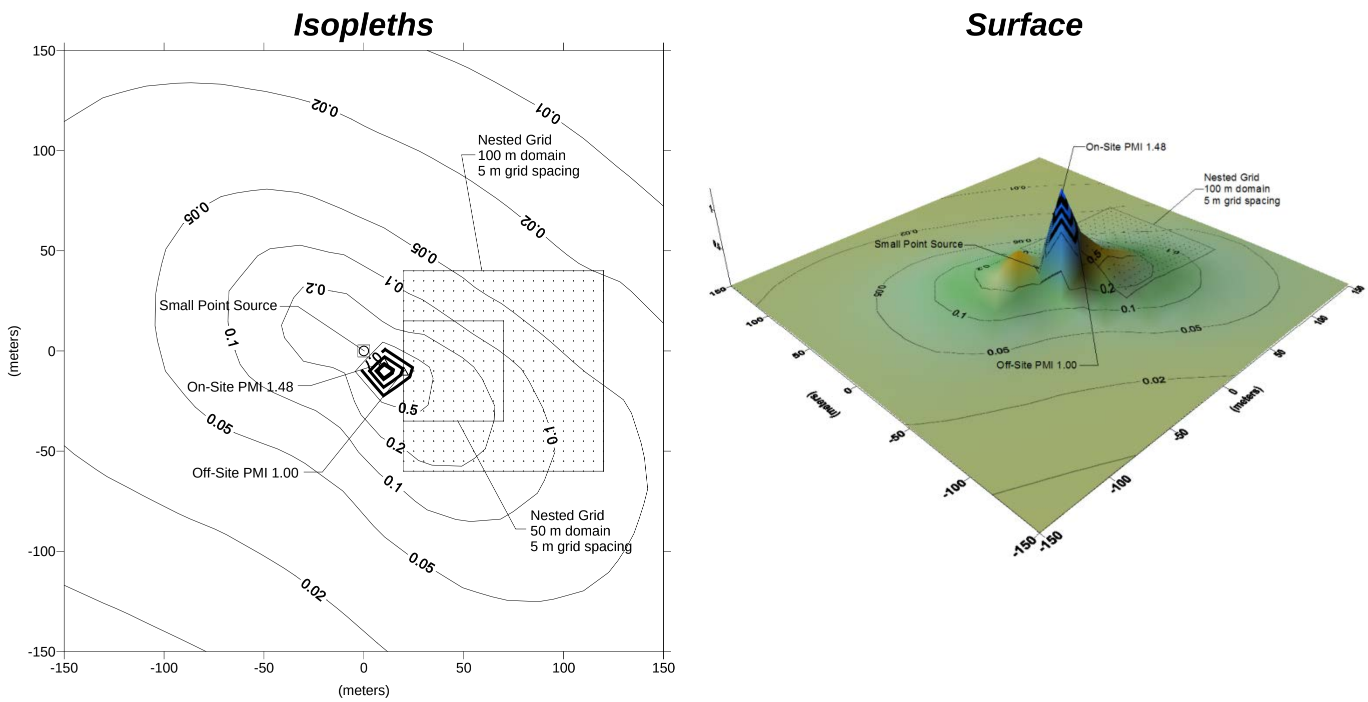


Figure AP C-3.3.3 – Small Point Source – Kearny Mesa

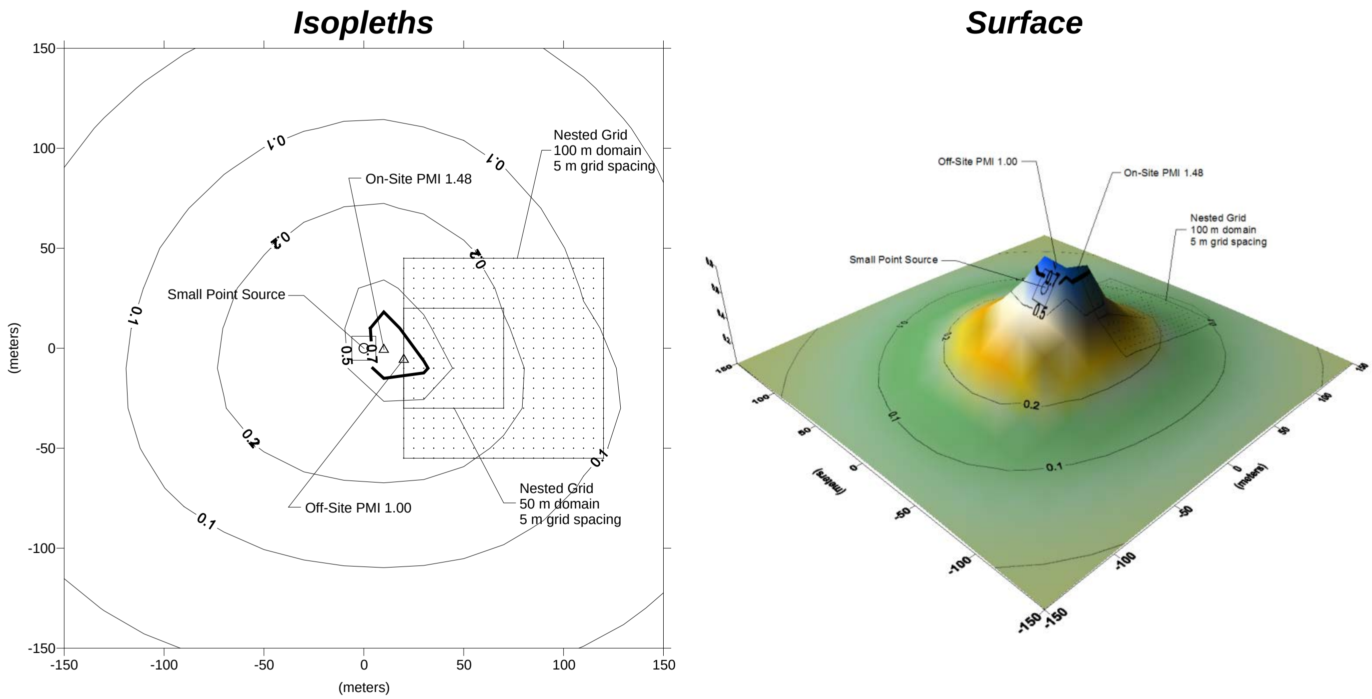


Figure AP C-3.3.4 – Small Point Source – Lynwood

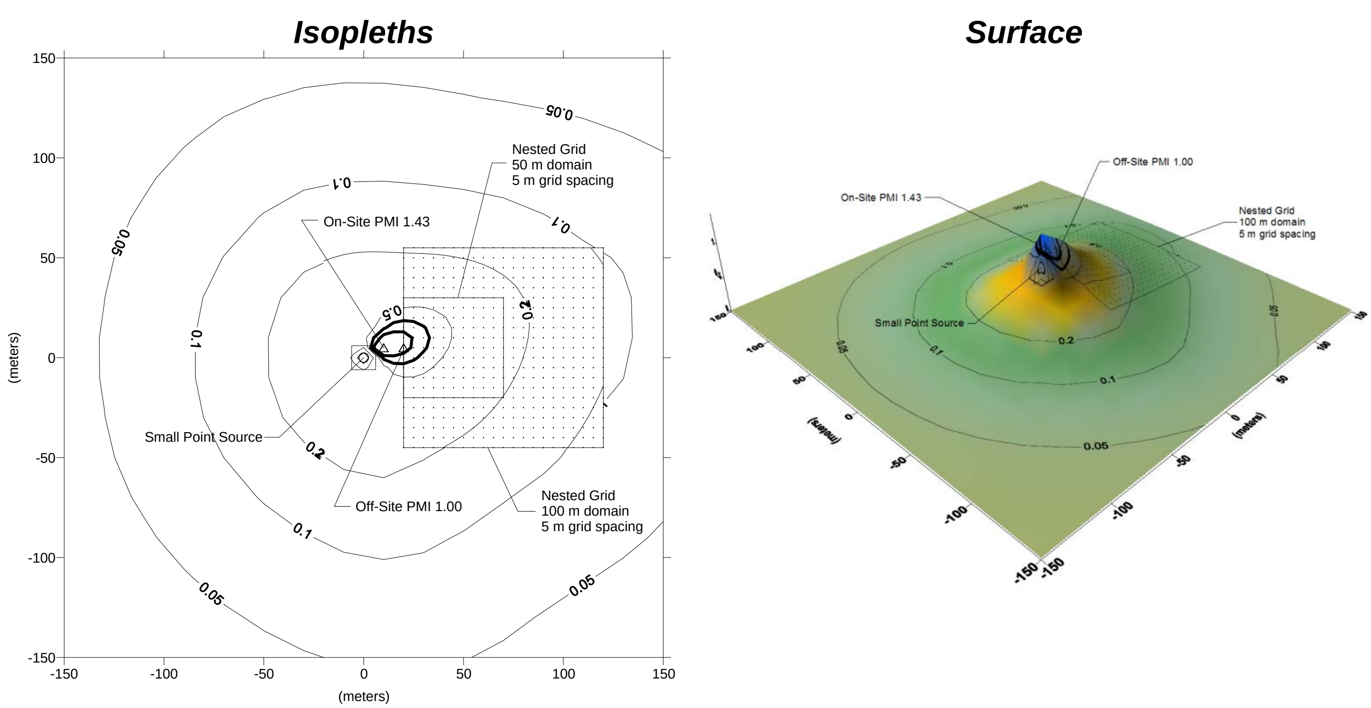


Figure AP C-3.3.5 – Small Point Source – San Bernardino

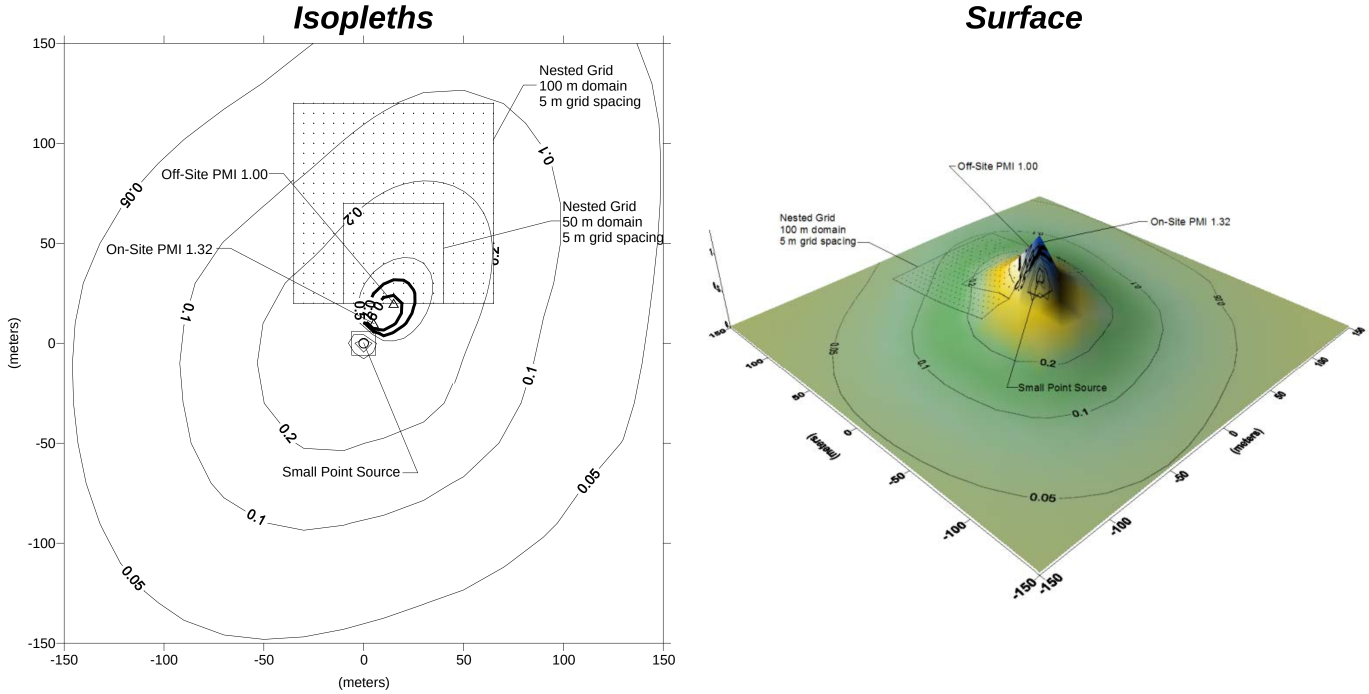


Figure AP C-3.4.1 – Large Volume Source – Costa Mesa

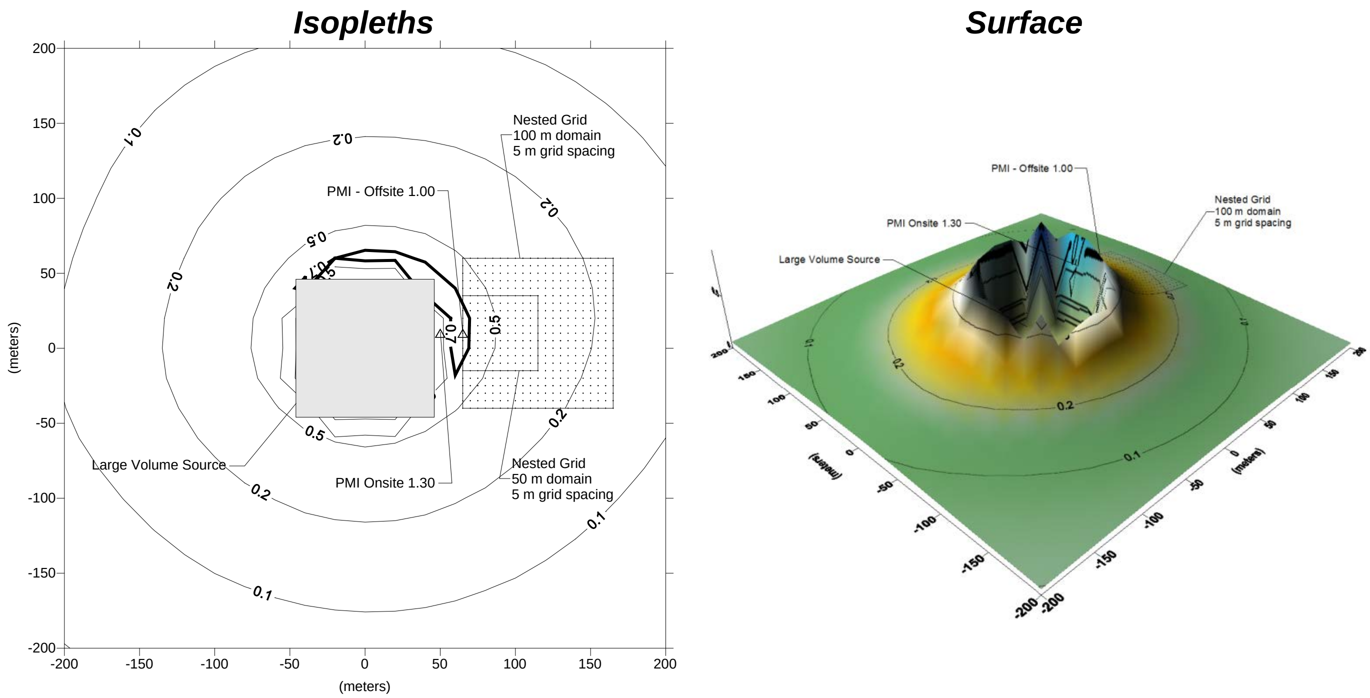


Figure AP C-3.4.2 – Large Volume Source – Fresno Air Terminal

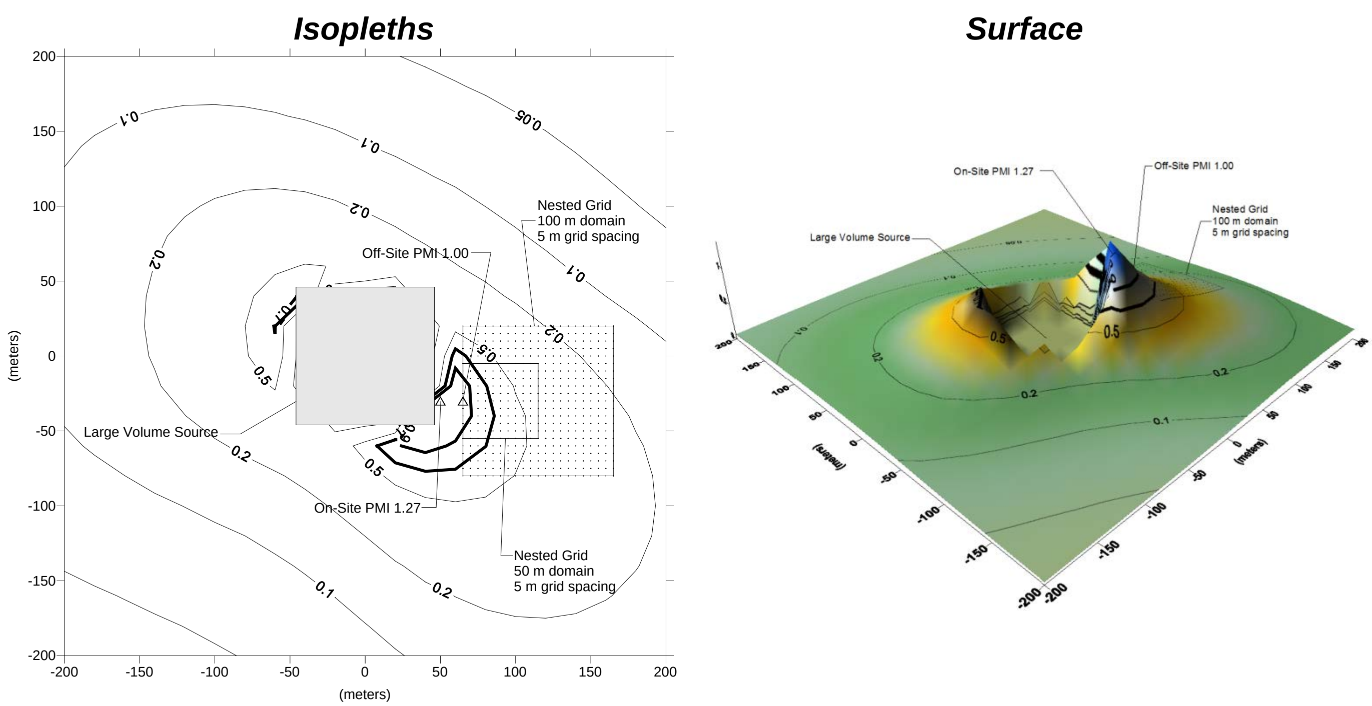
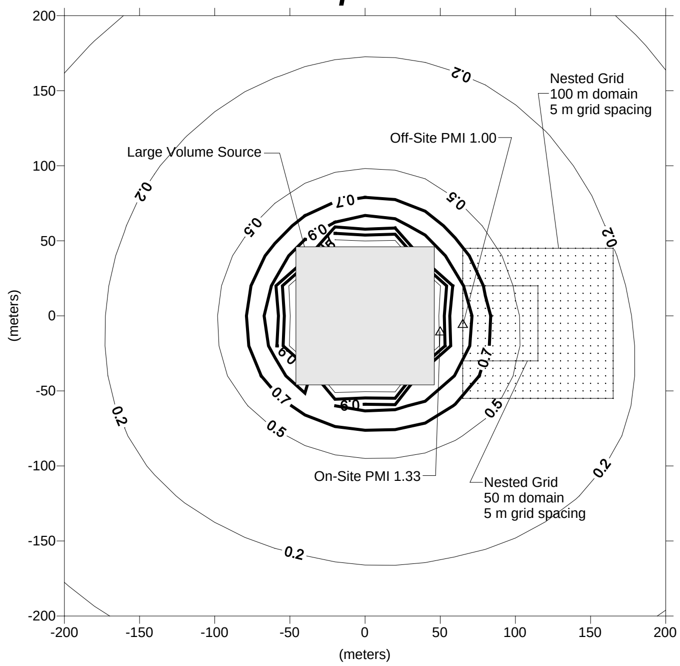


Figure AP C-3.4.3 – Large Volume Source – Kearny Mesa

Isopleths



Surface

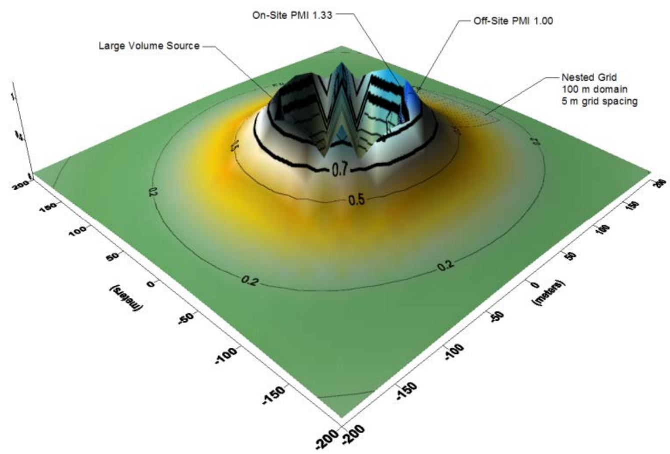
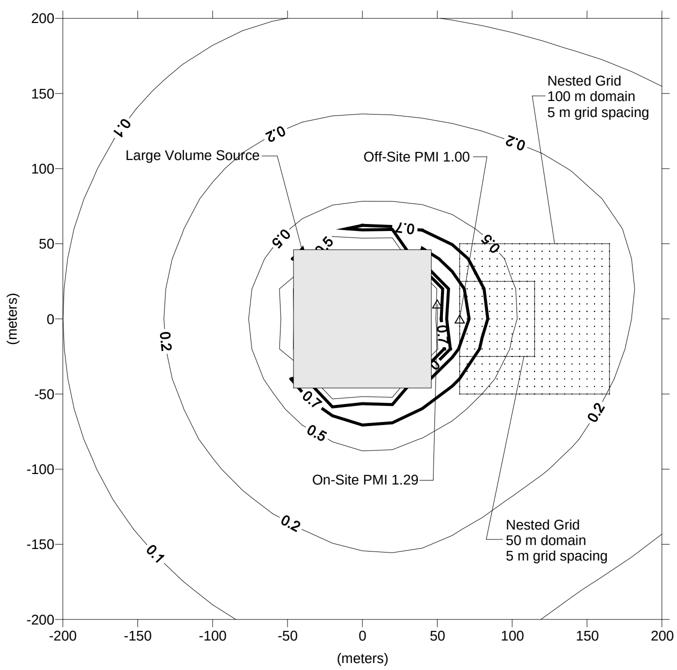


Figure AP C-3.4.4 – Large Volume Source – Lynwood

Isopleths



Surface

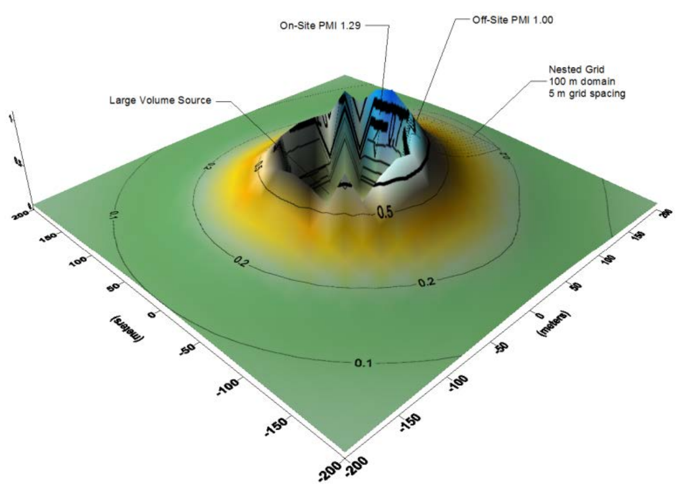


Figure AP C-3.4.5 – Large Volume Source – San Bernardino

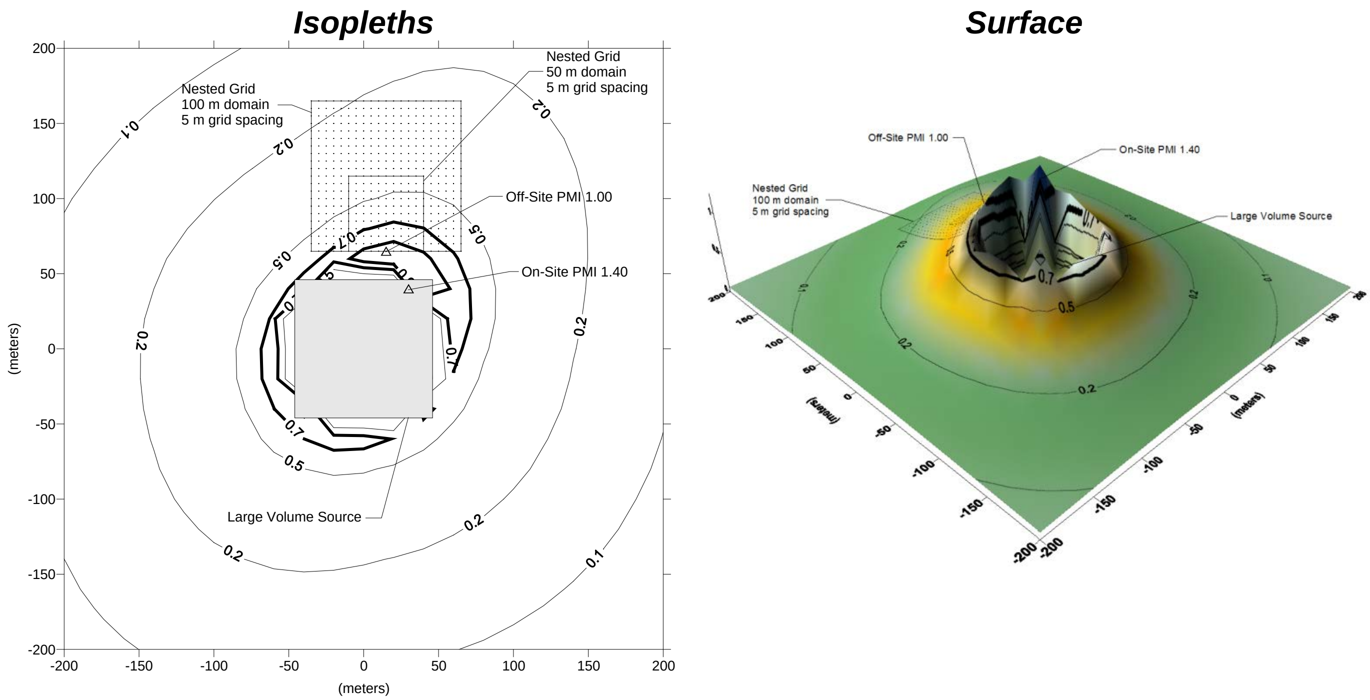


Figure AP C-3.5.1 – Medium Volume Source – Costa Mesa

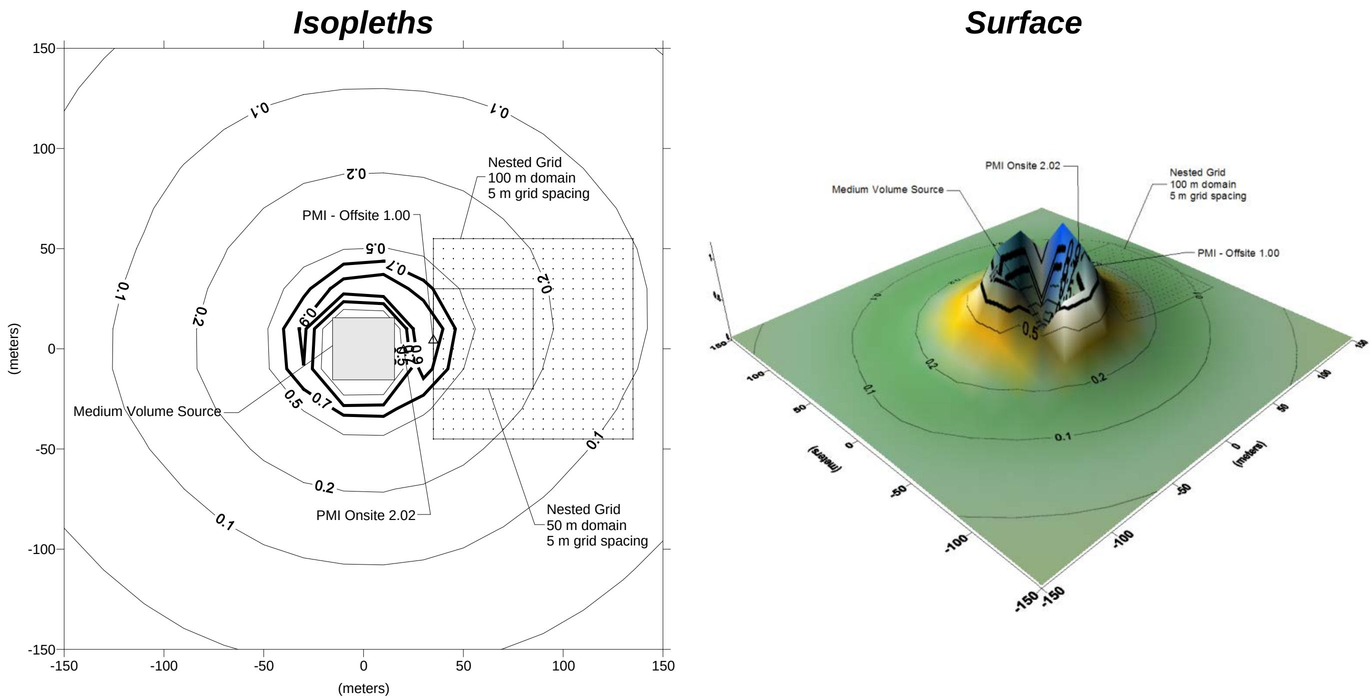


Figure AP C-3.5.2 – Medium Volume Source – Fresno Air Terminal

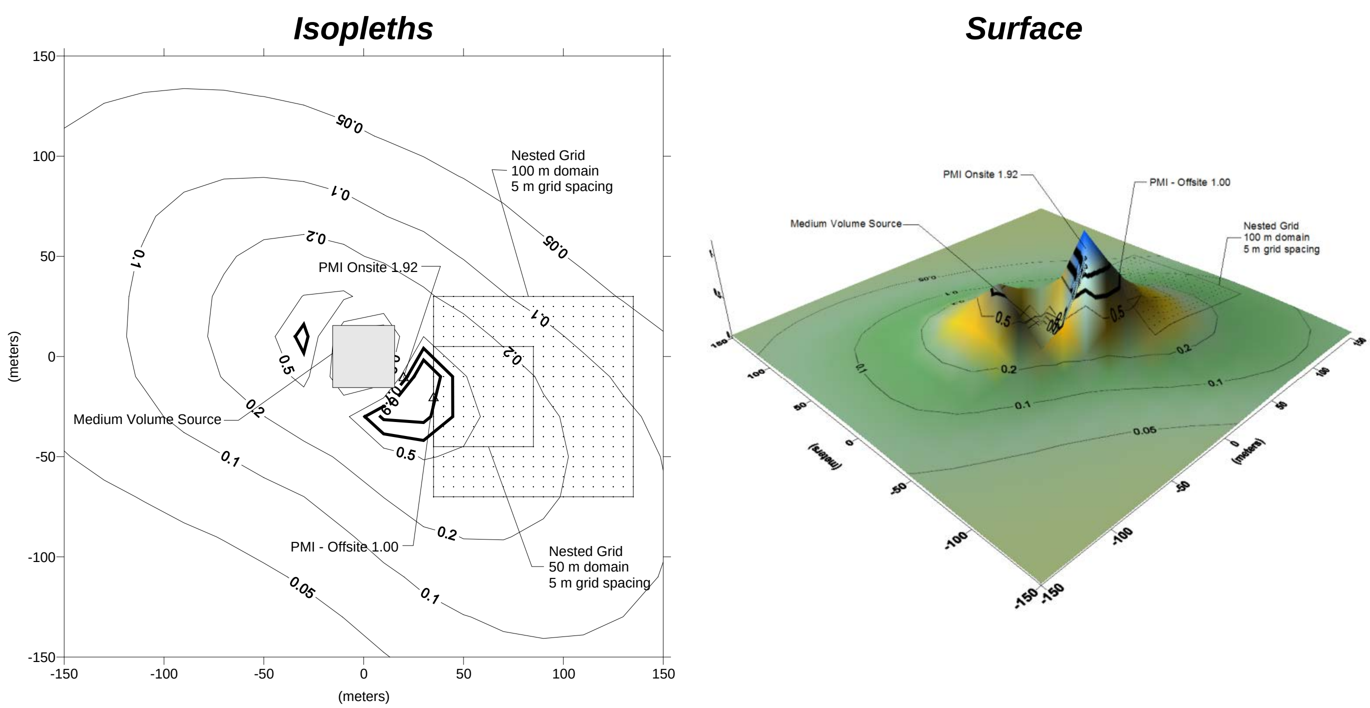
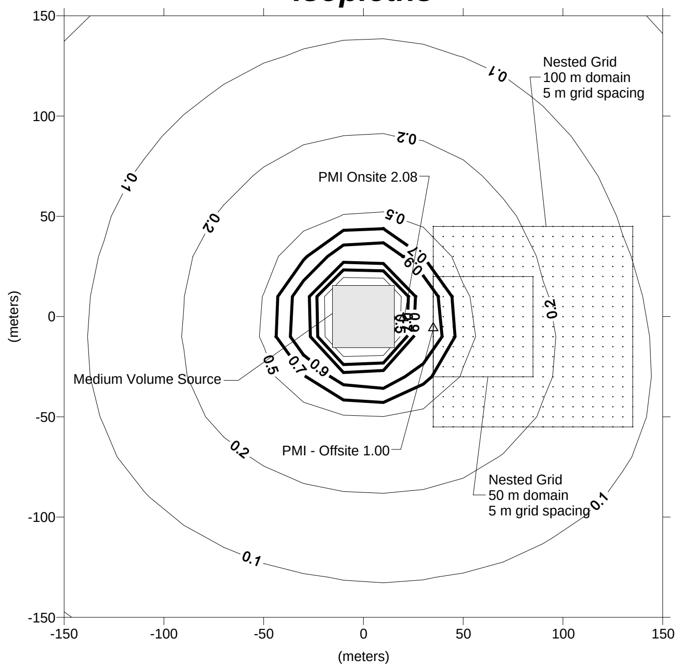


Figure AP C-3.5.3 – Medium Volume Source – Kearny Mesa

Isopleths



Surface

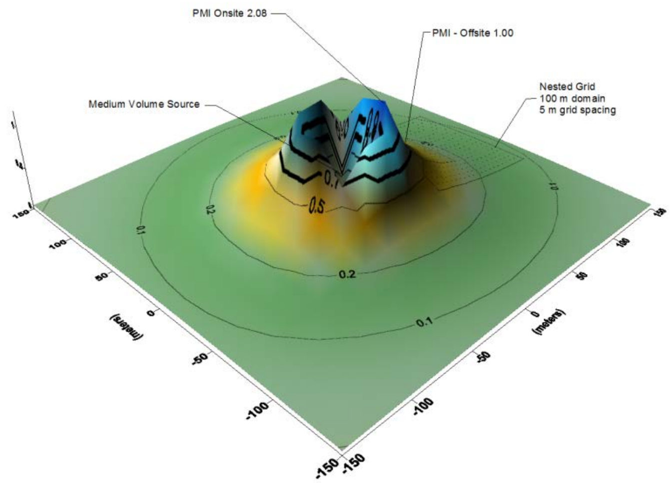
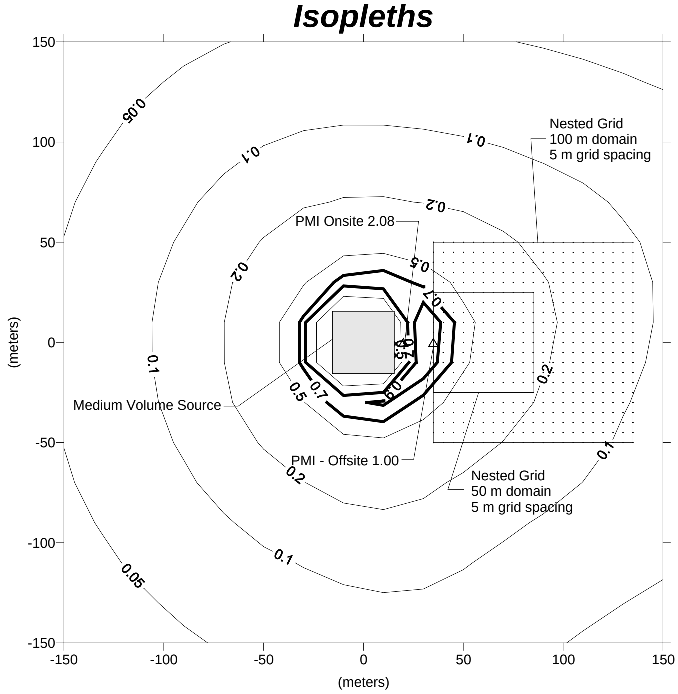


Figure AP C-3.5.4 – Medium Volume Source – Lynnwood

Isopleths



Surface

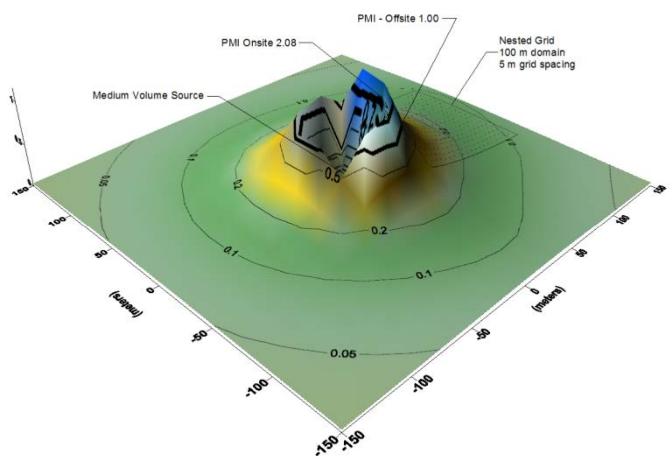


Figure AP C-3.5.5 – Medium Volume Source – San Bernardino

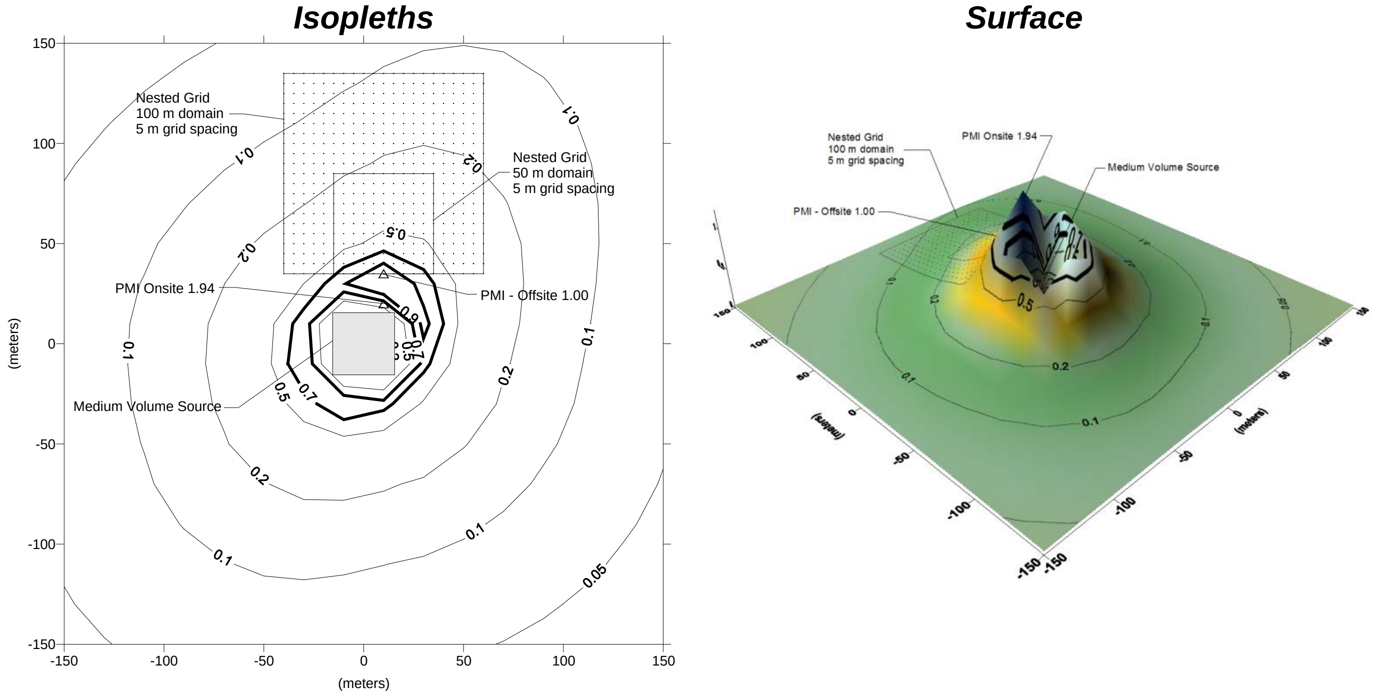


Figure AP C-3.6.1 – Small Volume Source – Costa Mesa

Isopleths ***Surface***

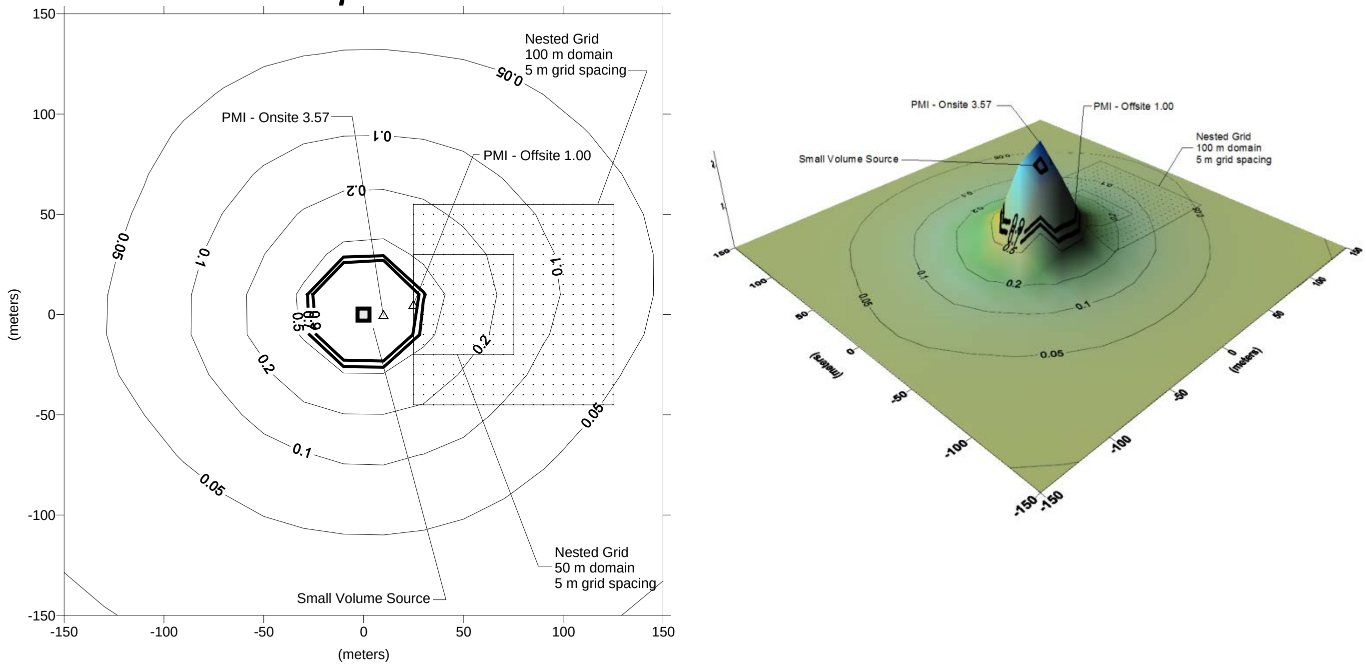


Figure AP C-3.6.2 – Small Volume Source – Fresno Air Terminal

Isopleths ***Surface***

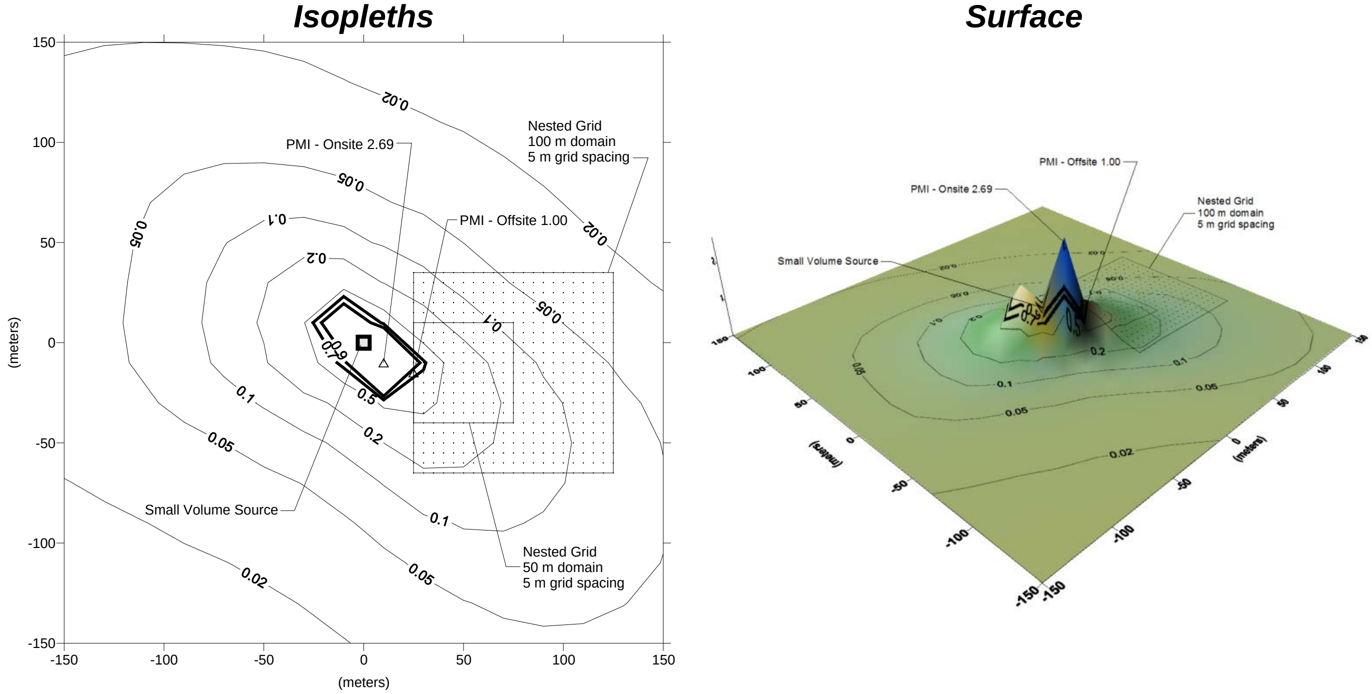
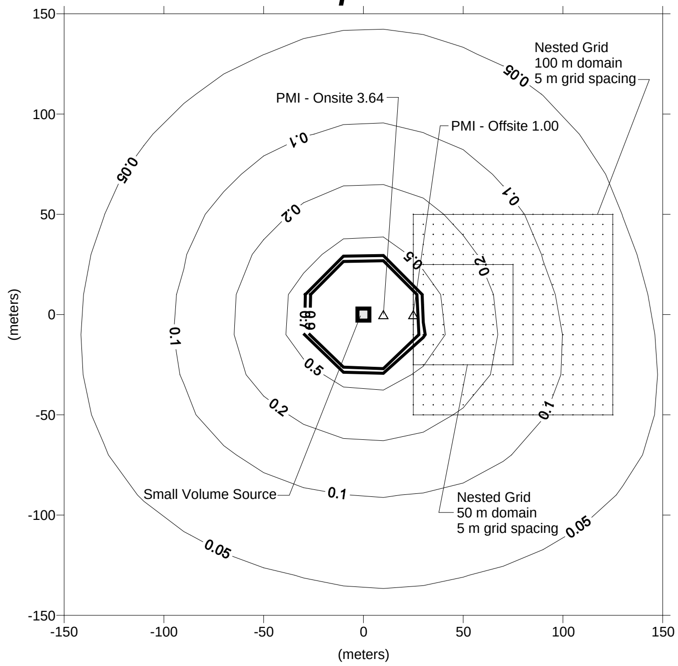


Figure AP C-3.6.3 – Small Volume Source – Kearny Mesa

Isopleths



Surface

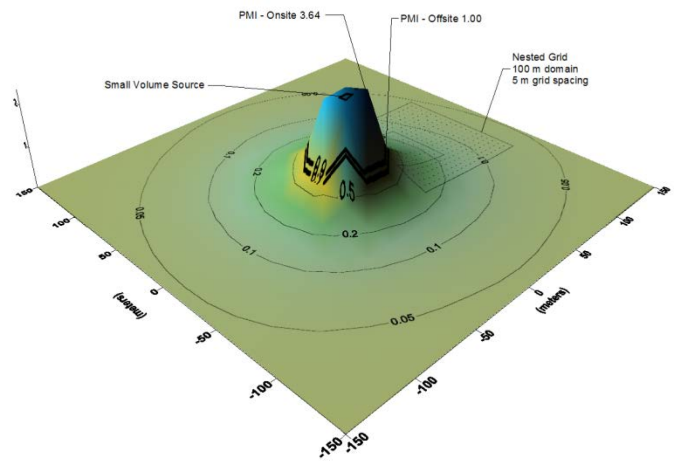
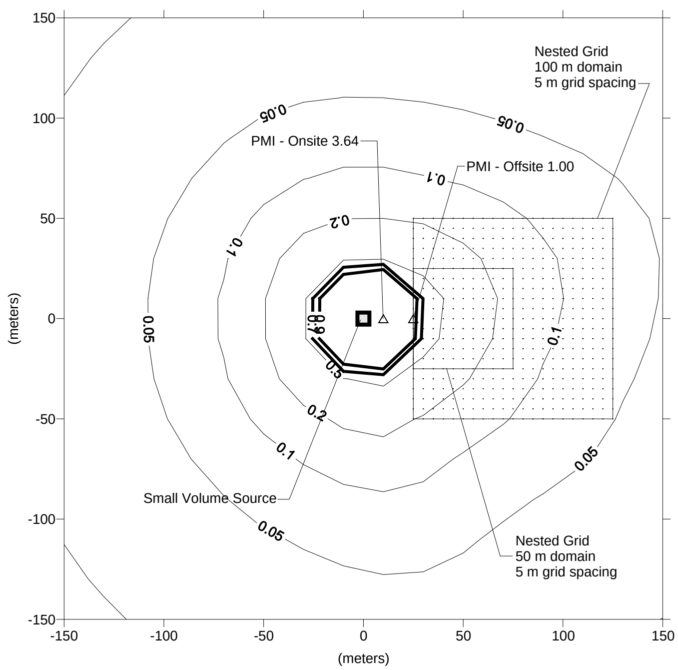


Figure AP C-3.6.4 – Small Volume Source – Lynnwood

Isopleths



Surface

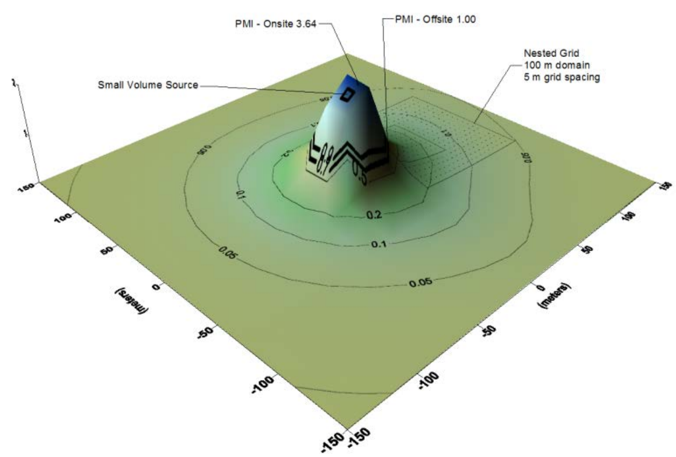
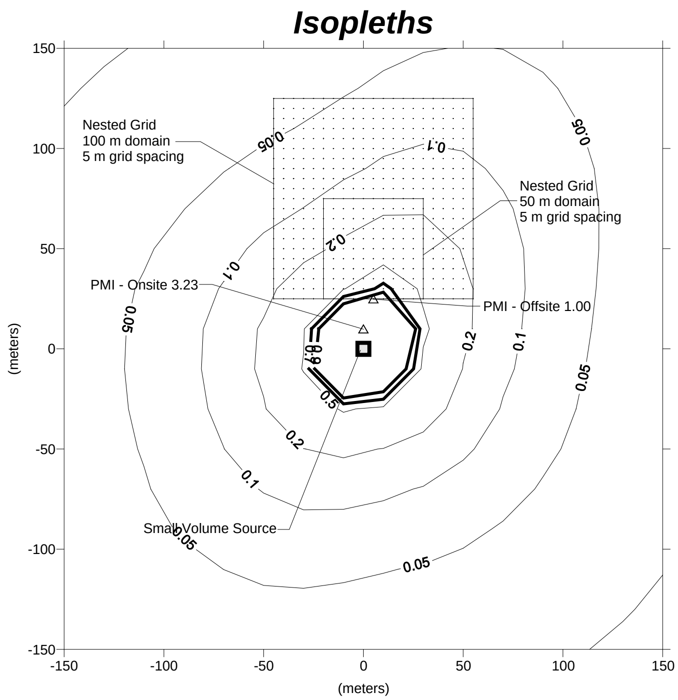


Figure AP C-3.6.5 – Small Volume Source – San Bernardino



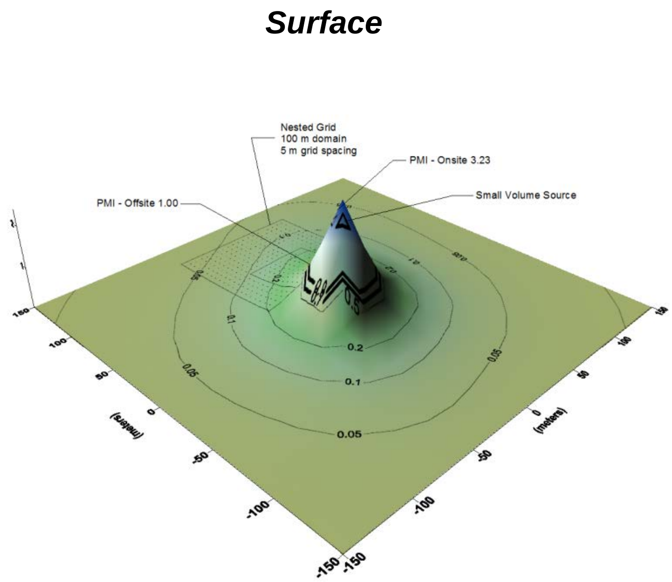
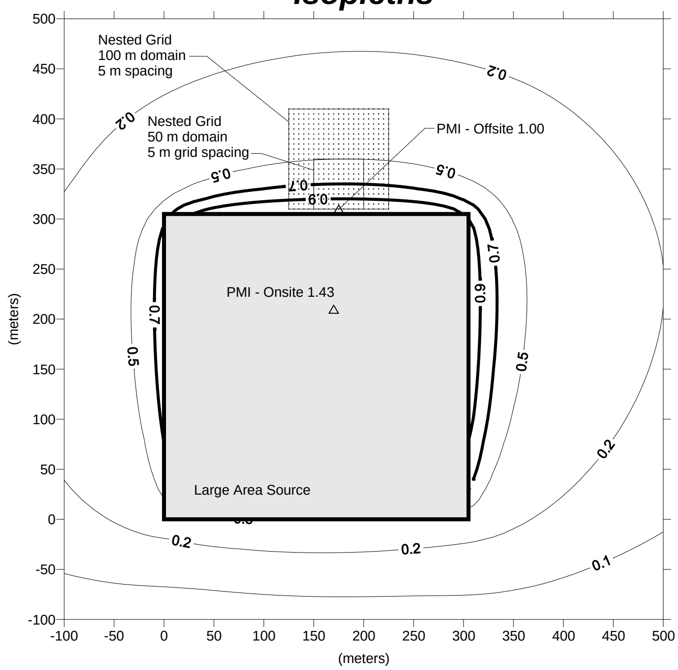


Figure AP C-3.7.1 – Large Area Source – Costa Mesa

Isopleths



Surface

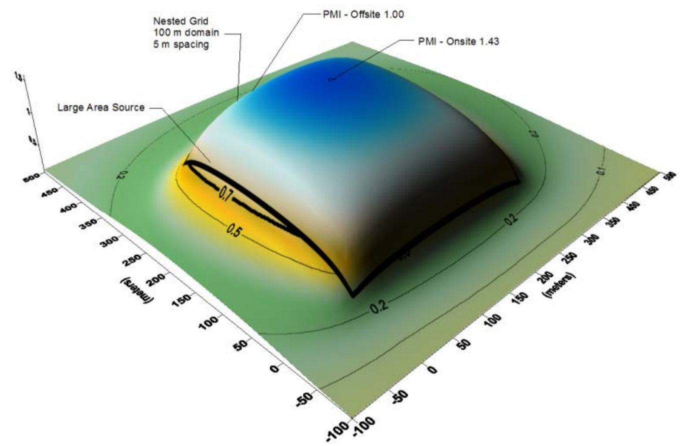
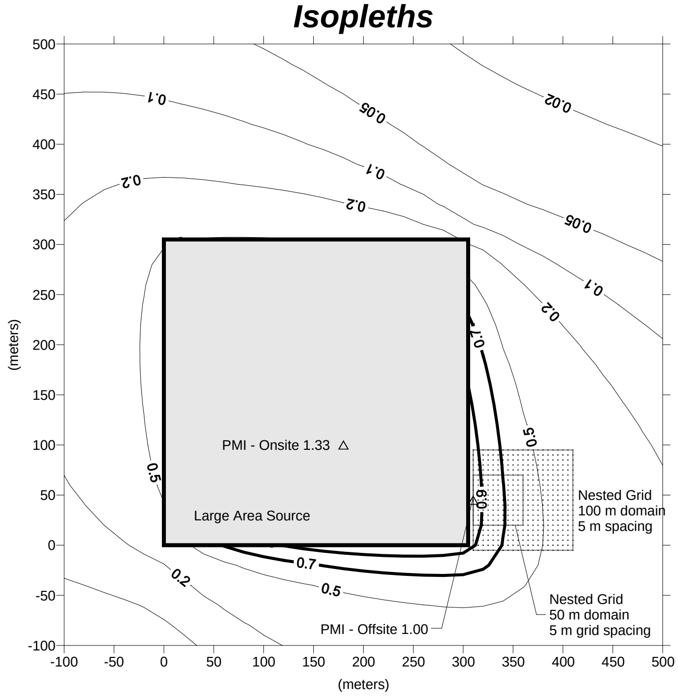


Figure AP C-3.7.2 – Large Area Source – Fresno Air Terminal

Isopleths



Surface

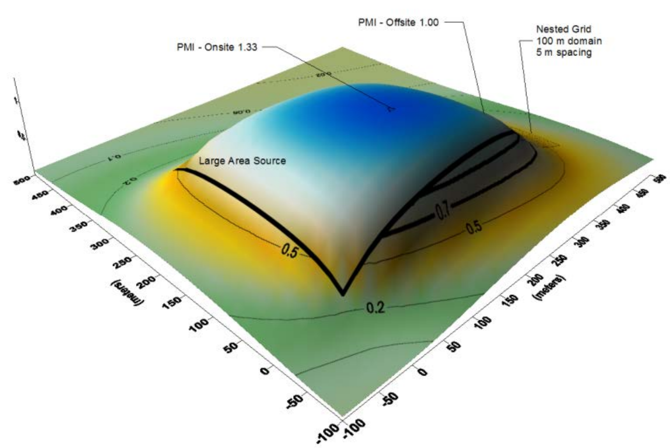


Figure AP C-3.7.3 – Large Area Source – Kearny Mesa

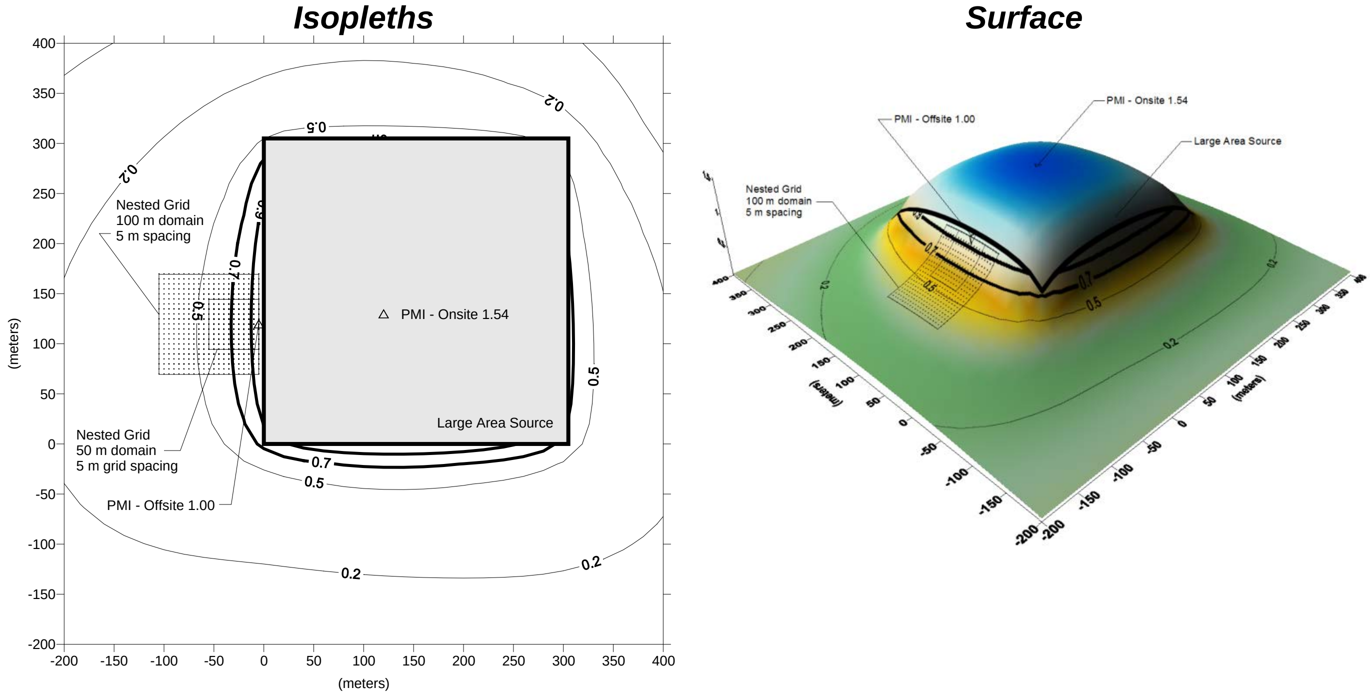


Figure AP C-3.7.4 – Large Area Source – Lynwood

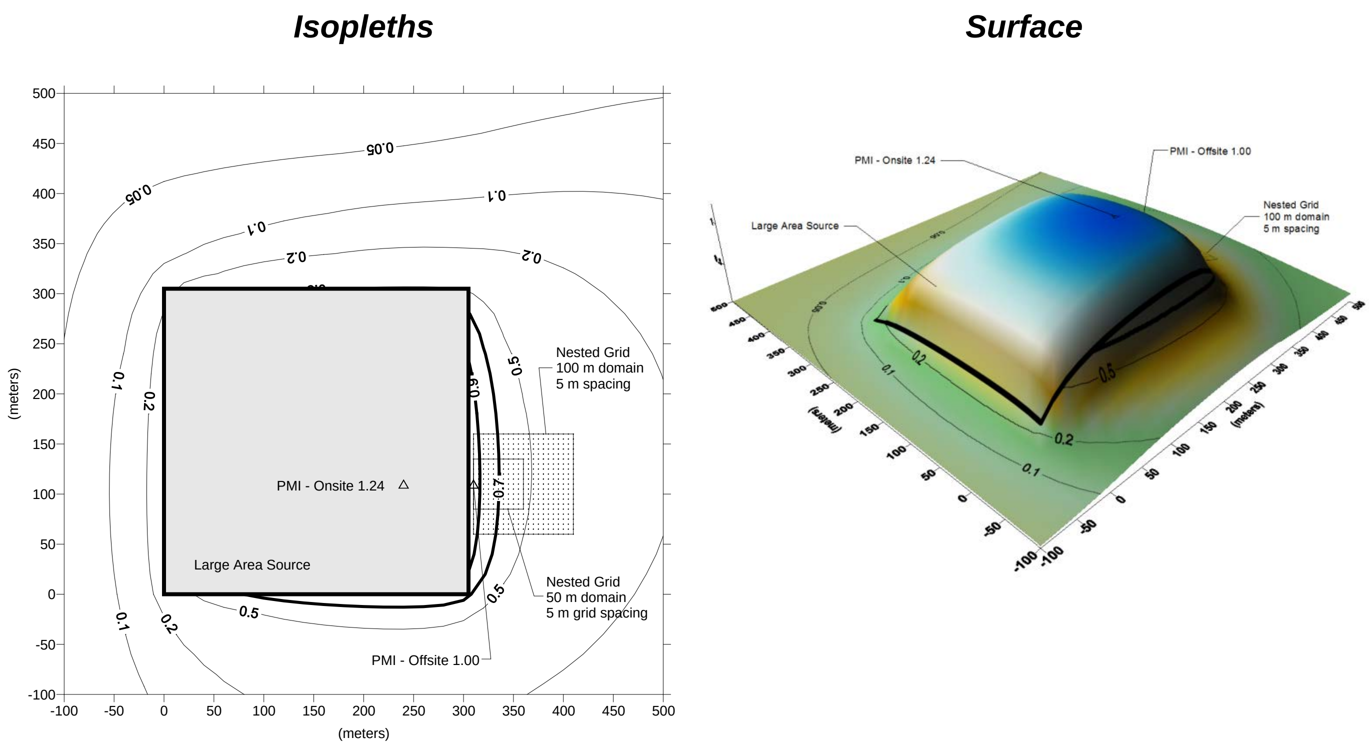


Figure AP C-3.7.5 – Large Area Source – San Bernardino

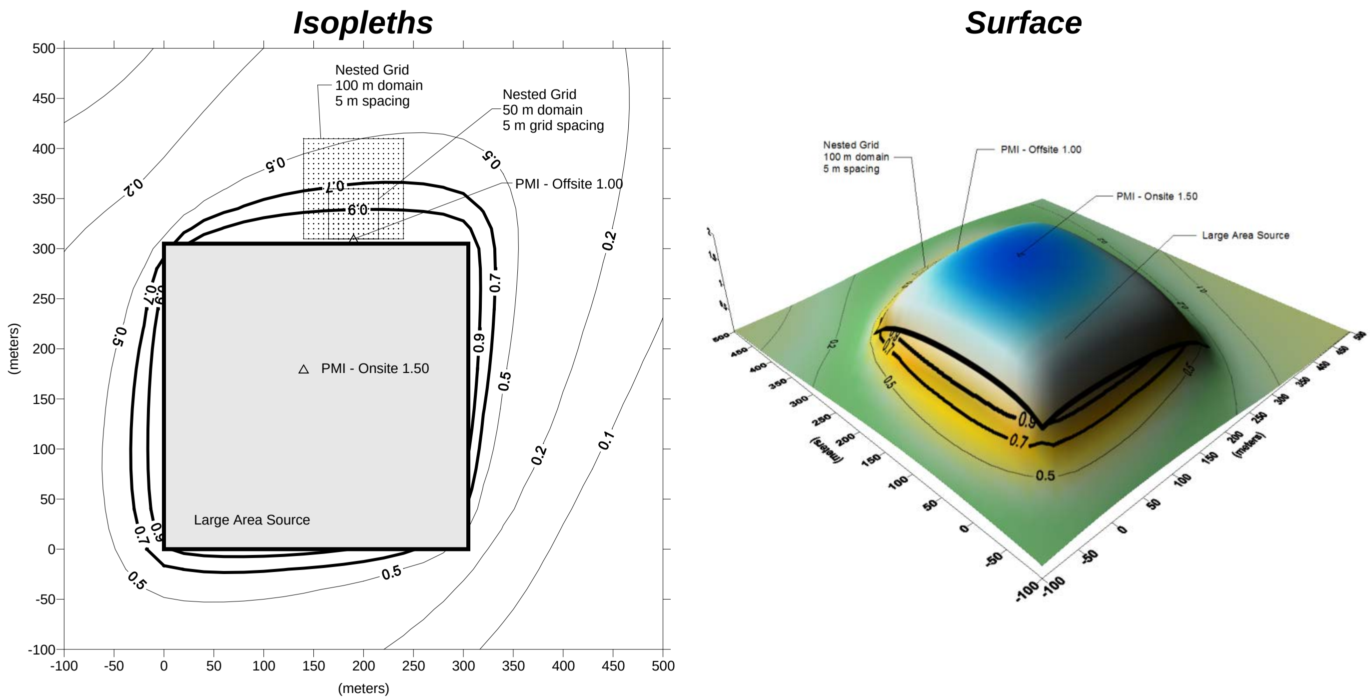


Figure AP C-3.8.1 – Medium Area Source – Costa Mesa

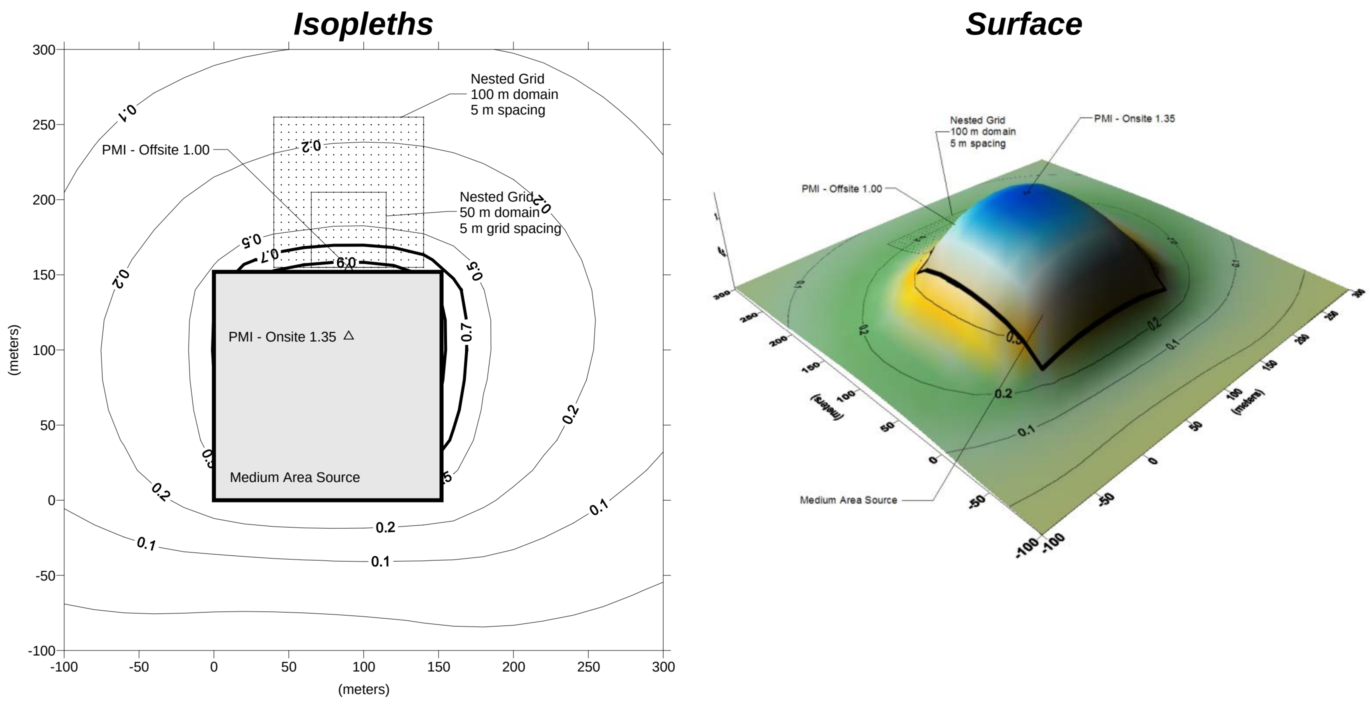


Figure AP C-3.8.2 – Medium Area Source – Fresno Air Terminal

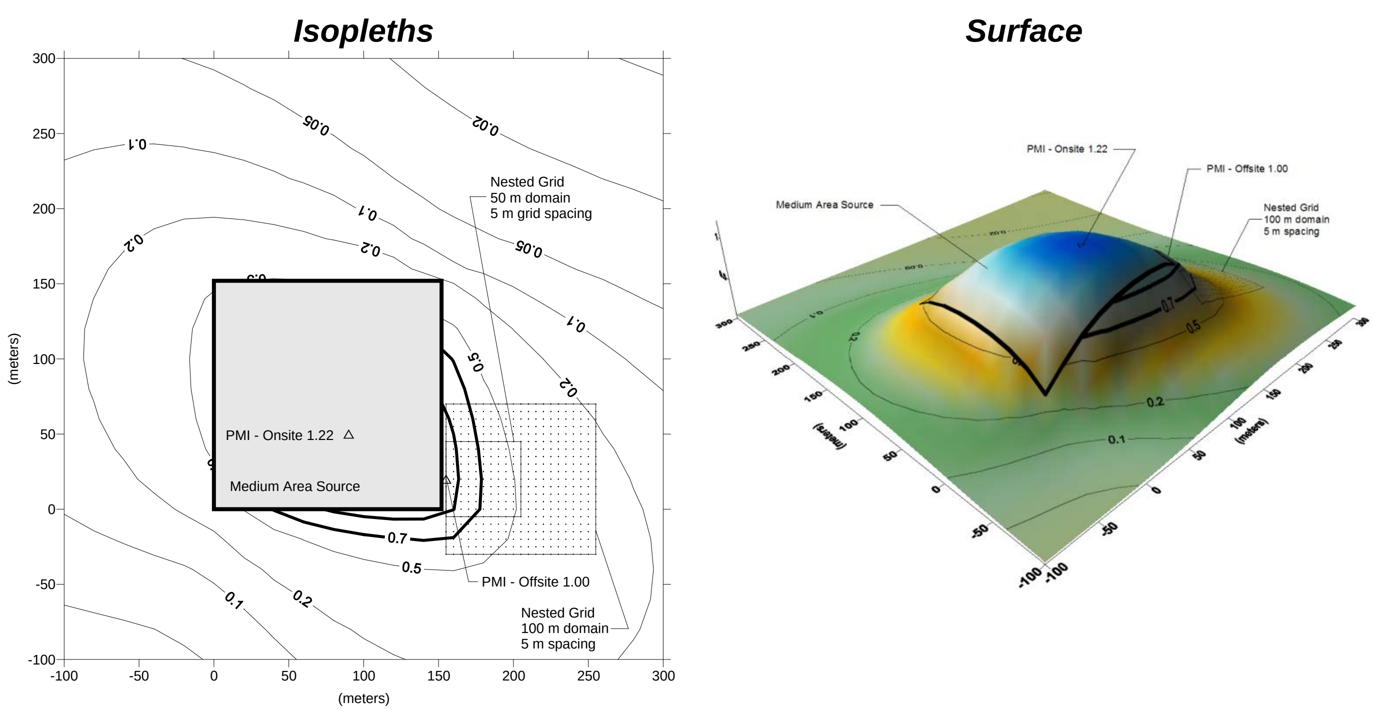


Figure AP C-3.8.3 – Medium Area Source – Kearny Mesa

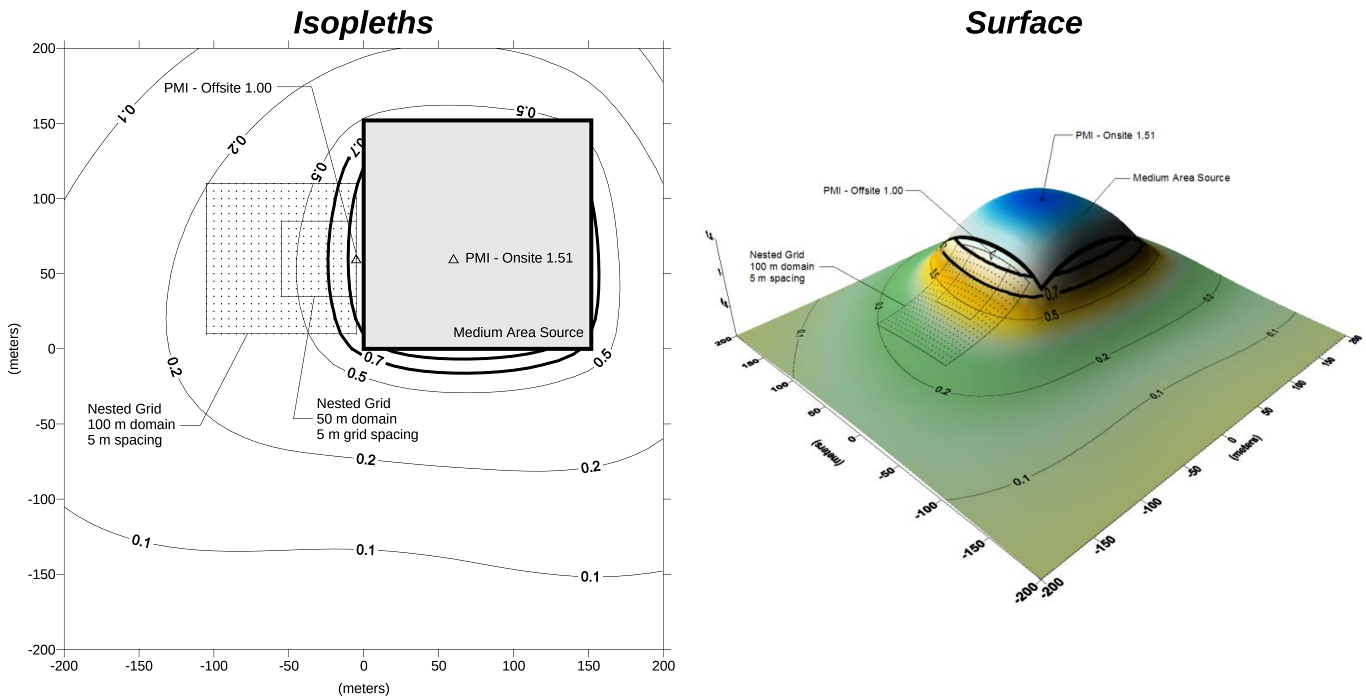


Figure AP C-3.8.4 – Medium Area Source – Lynwood

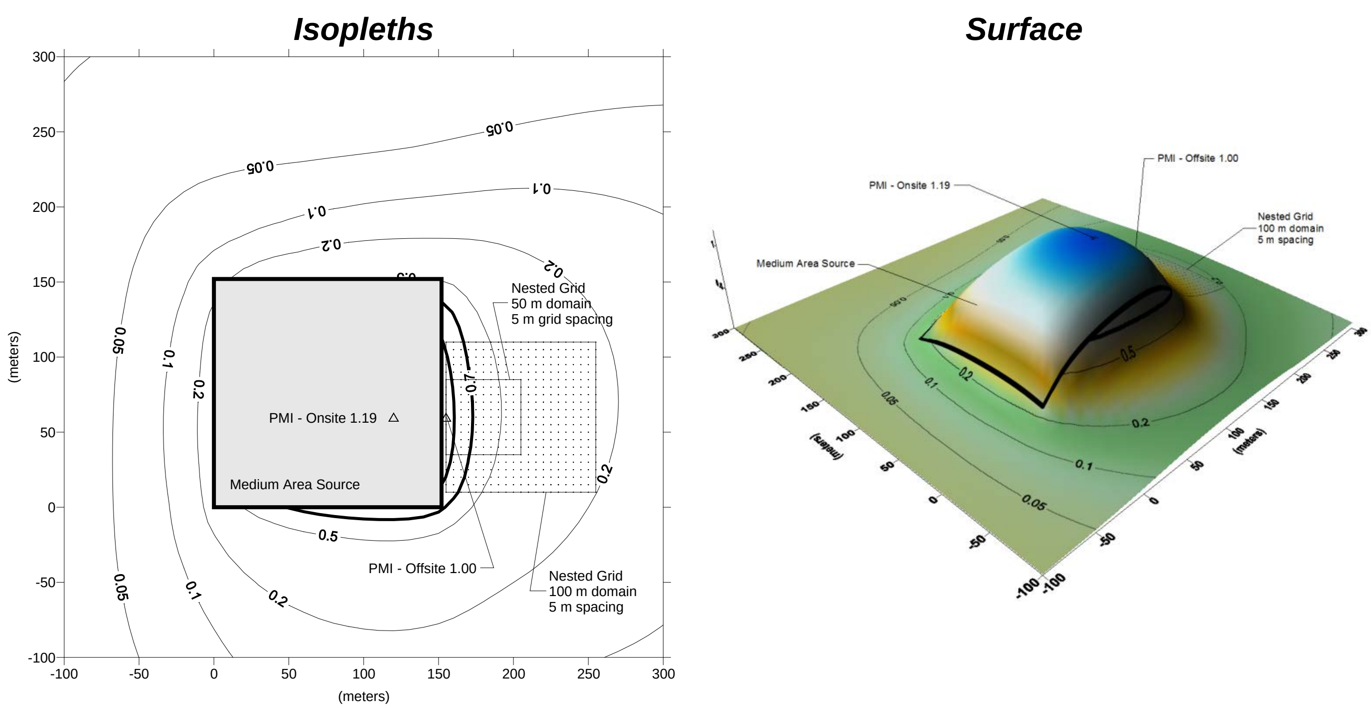
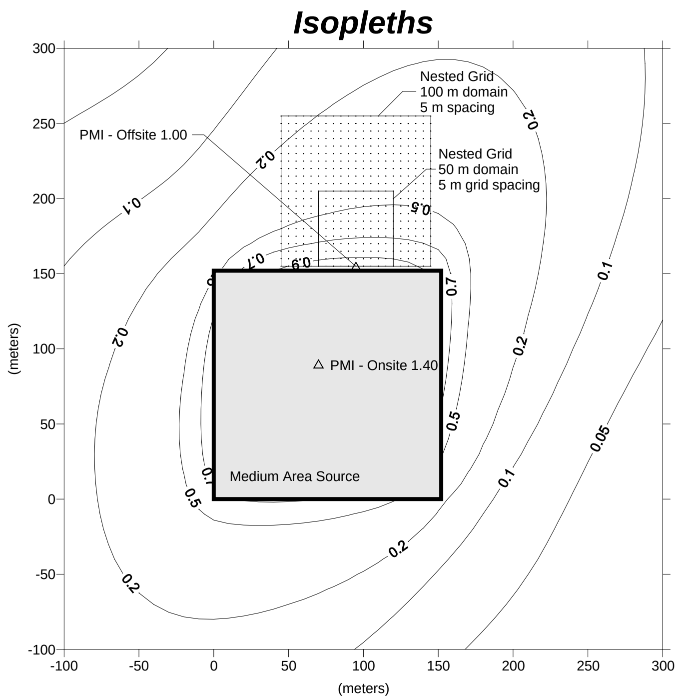


Figure AP C-3.8.5 – Medium Area Source – San Bernardino



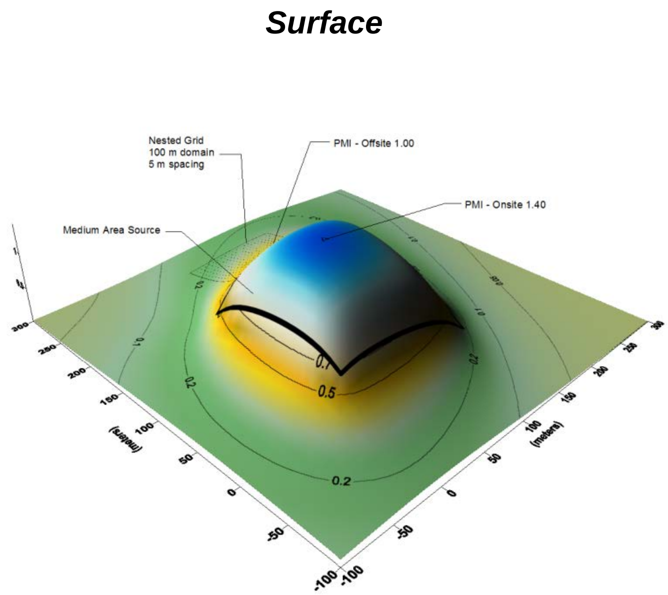


Figure AP C-3.9.1 – Small Area Source – Costa Mesa

Isopleths ***Surface***

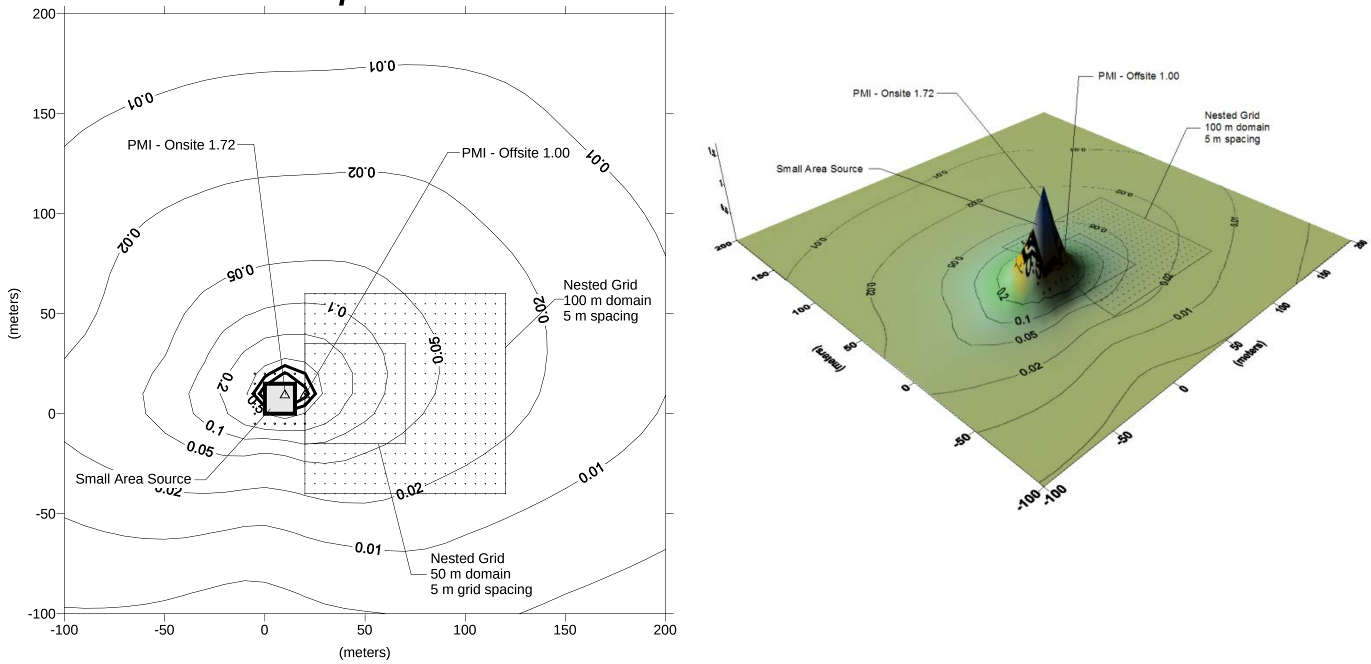


Figure AP C-3.9.2 – Small Area Source – Fresno Air Terminal

Isopleths ***Surface***

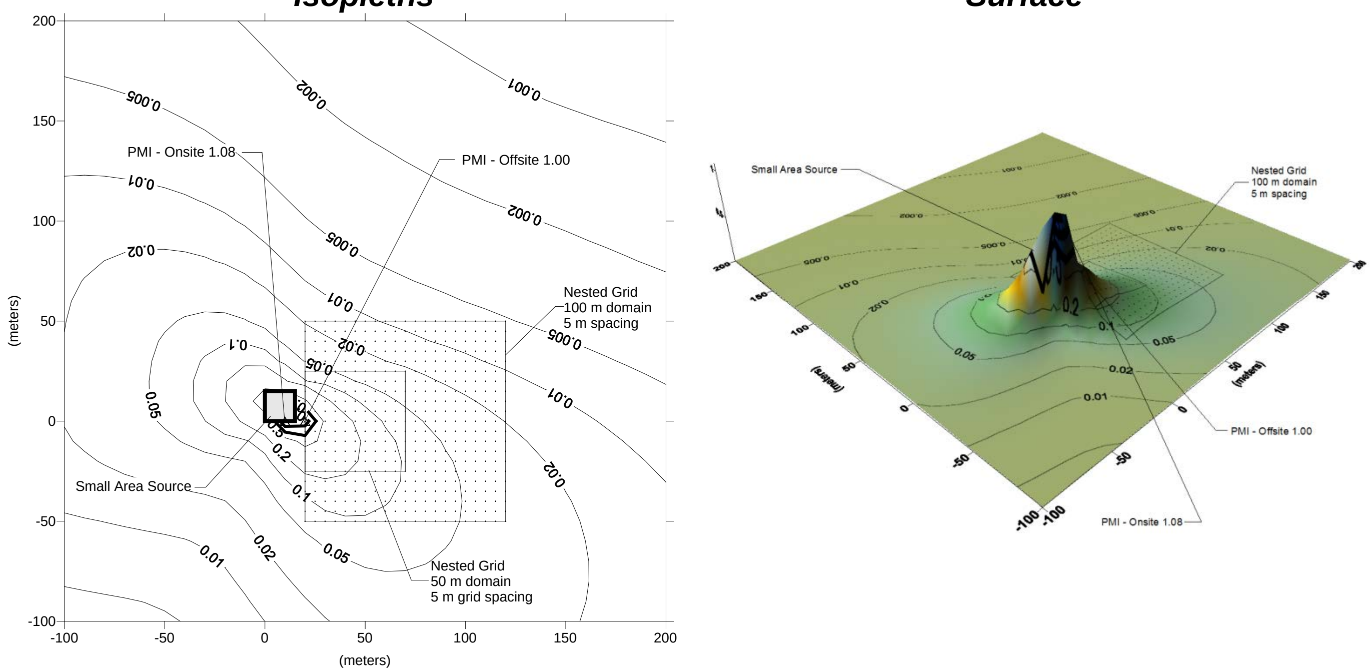


Figure AP C-3.9.3 – Small Area Source – Kearny Mesa

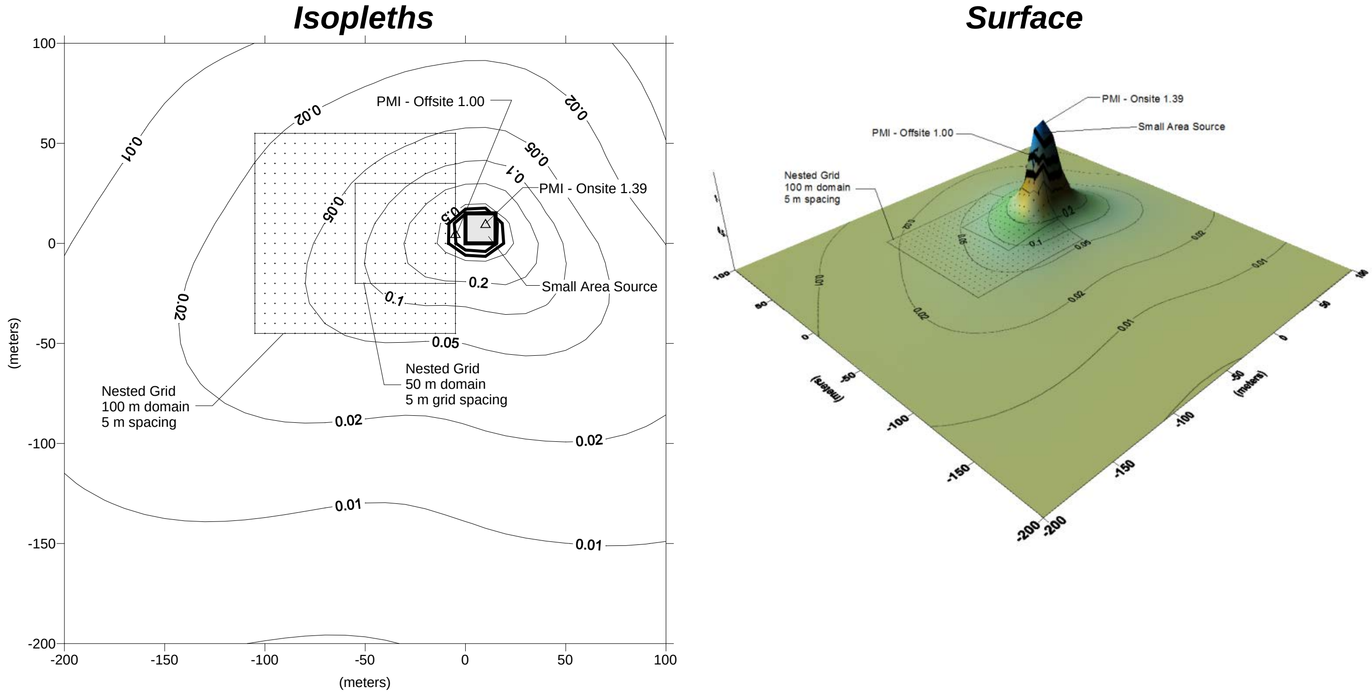


Figure AP C-3.9.4 – Small Area Source – Lynwood

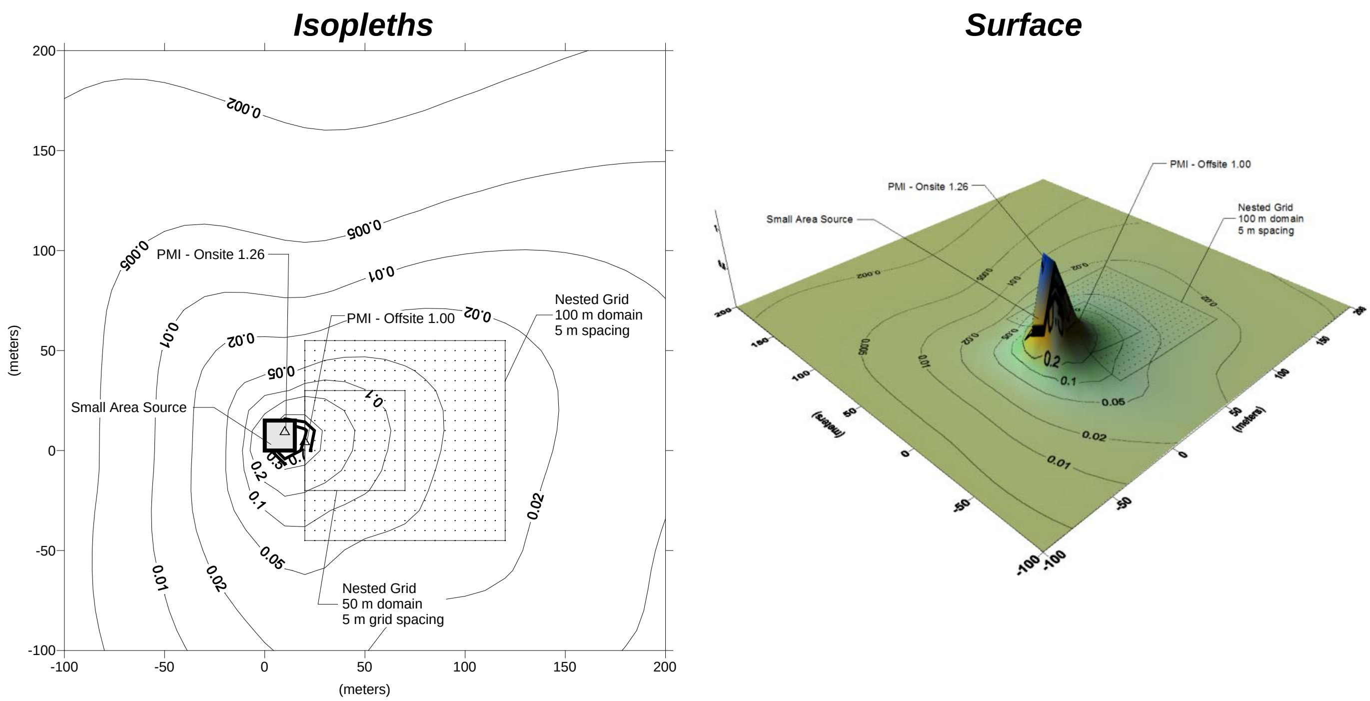
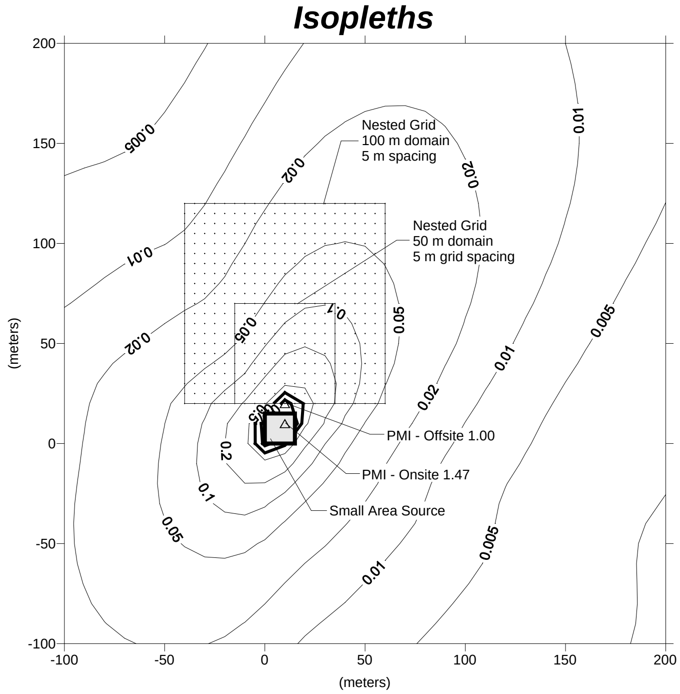


Figure AP C-3.9.5 – Small Area Source – San Bernardino



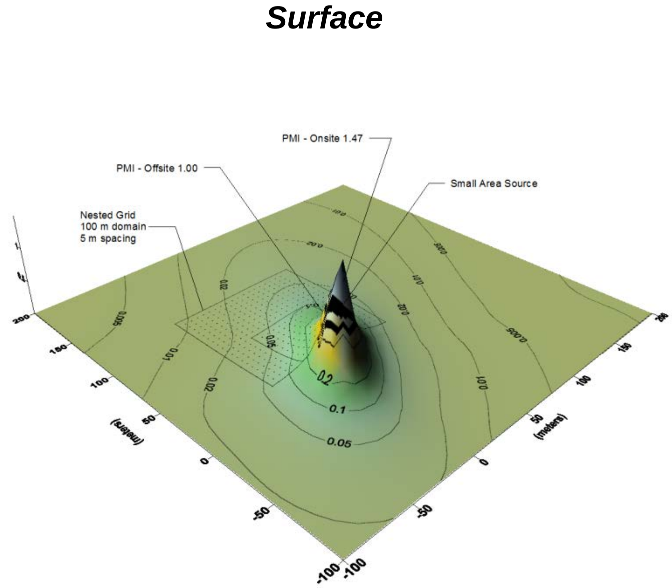


Figure AP C-3.10.1 – Large Line Source, CALINE – Costa Mesa

Isopleths | *Surface*

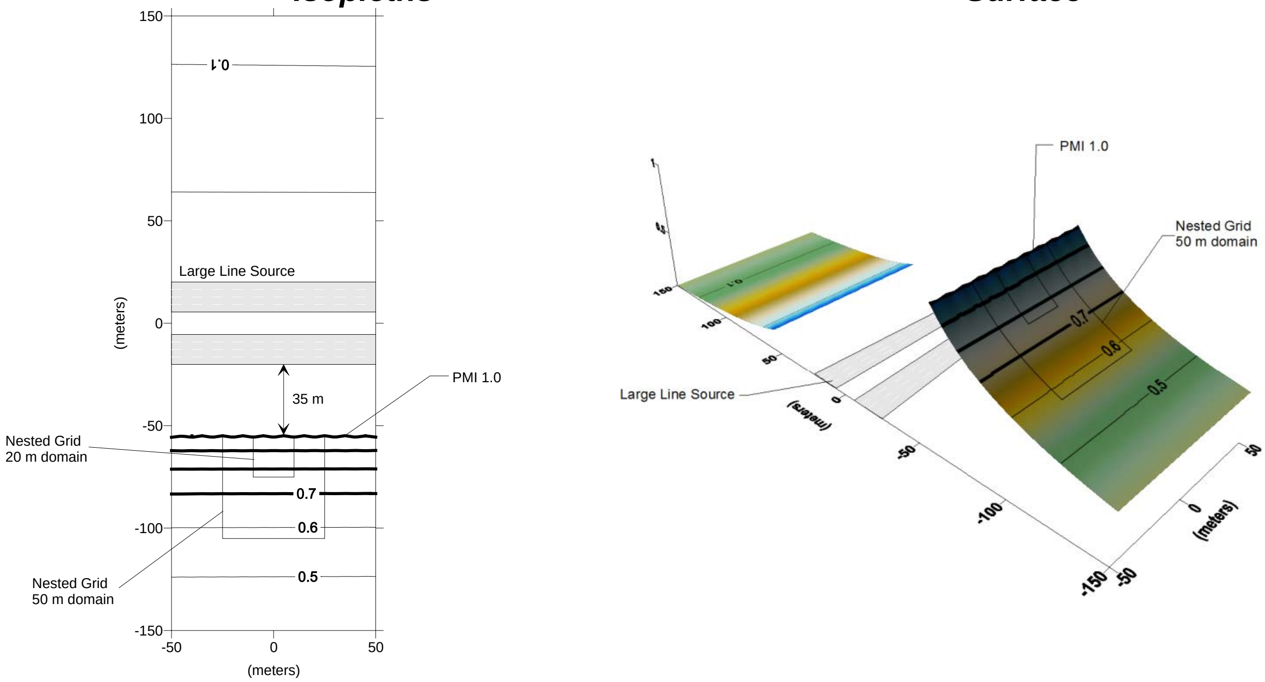


Figure AP C-3.10.2 – Large Line Source, CALINE – Fresno Air Terminal

Isopleths | *Surface*

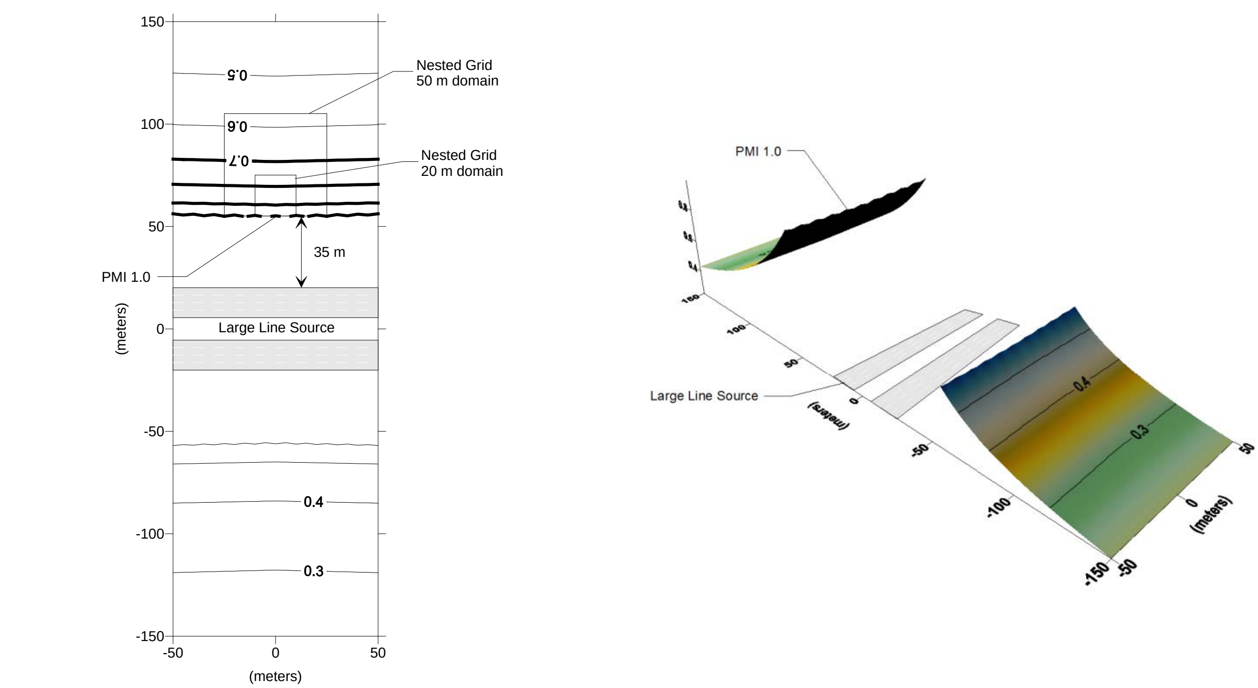


Figure AP C-3.10.3 – Large Line Source, CALINE – Kearny Mesa

Isopleths *Surface*

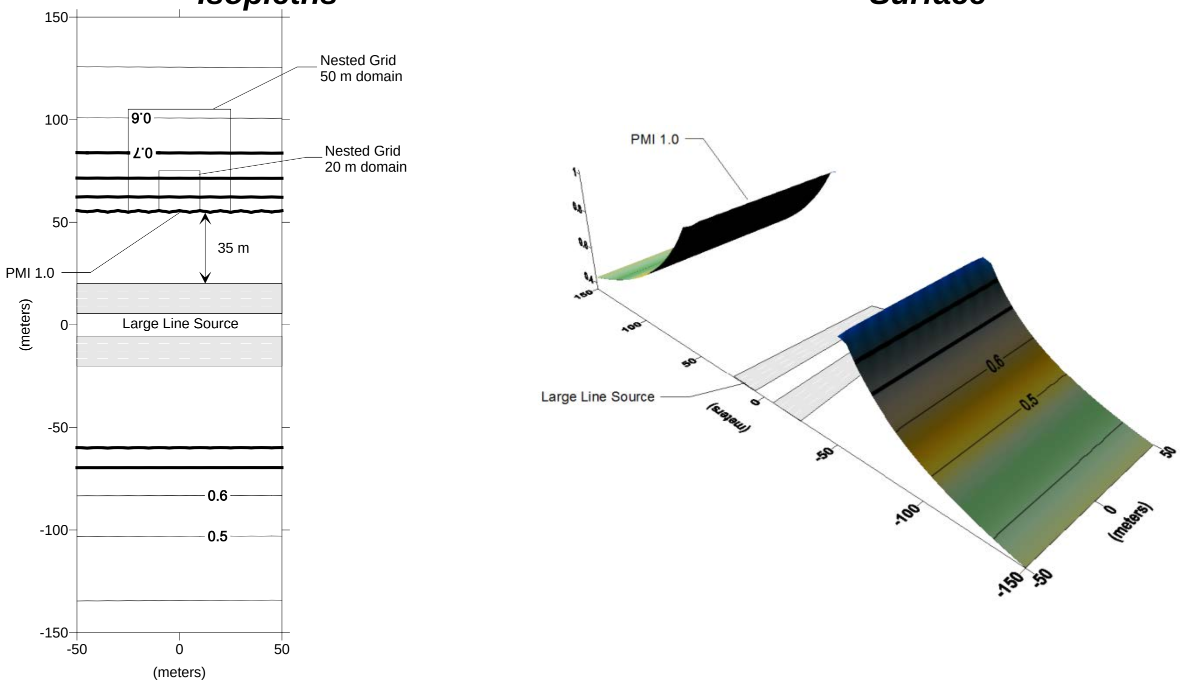


Figure AP C-3.10.4 – Large Line Source, CALINE – Lynwood

Isopleths *Surface*

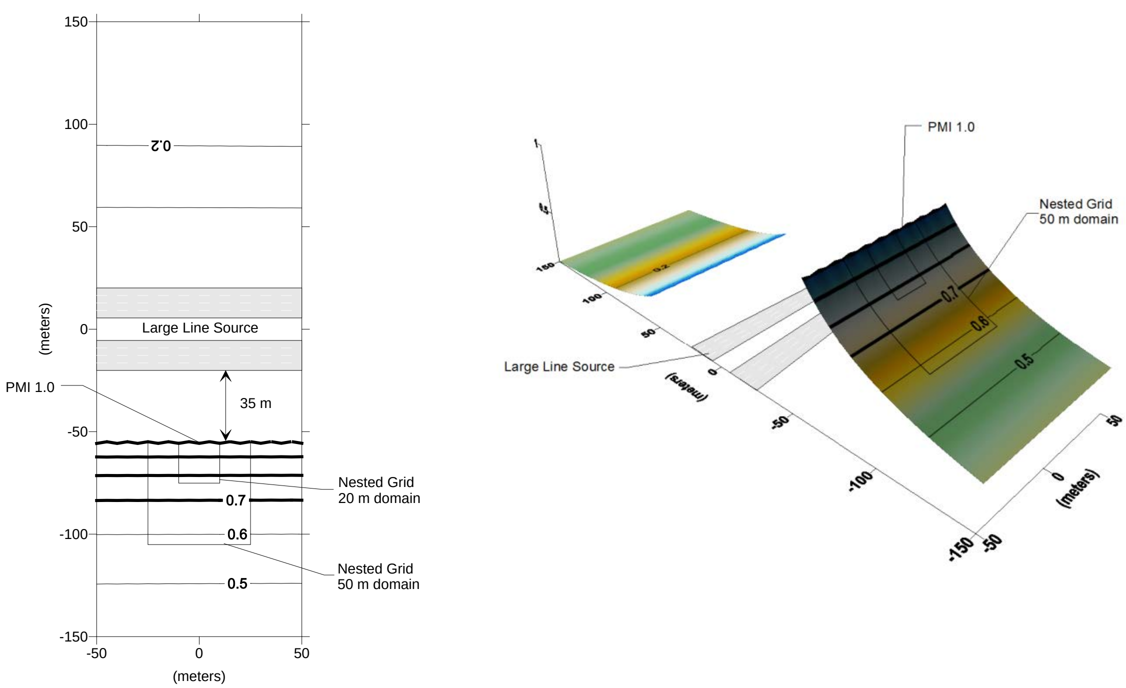
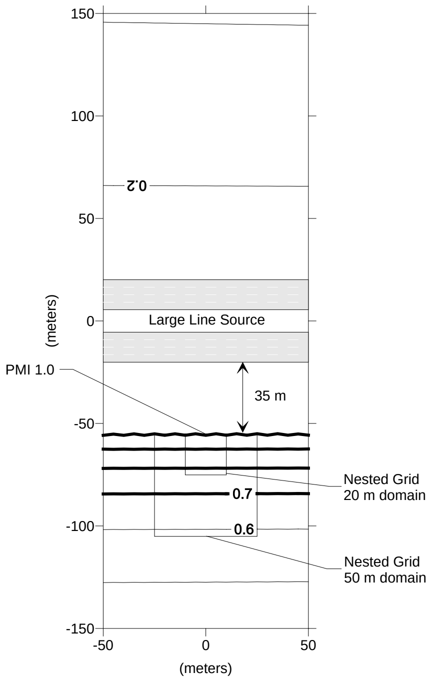


Figure AP C-3.10.5 – Large Line Source, CALINE – San Bernardino

Isopleths



Surface

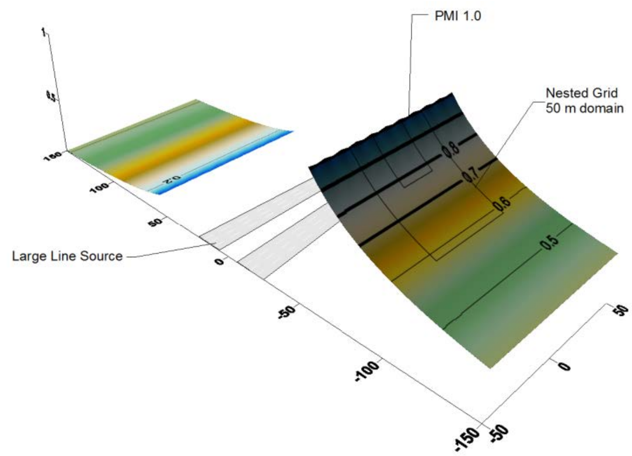


Figure AP C-3.11.1 – Small Line Source, CALINE – Costa Mesa

Isopleths ***Surface***

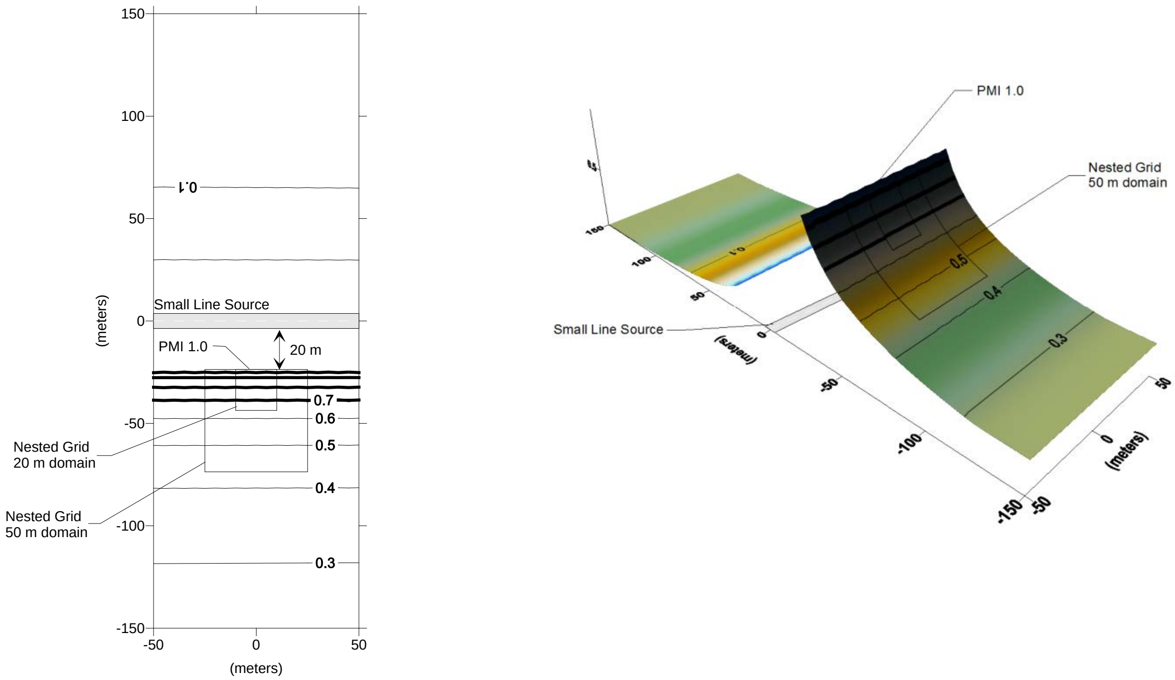


Figure AP C-3.11.2 – Small Line Source, CALINE – Fresno Air Terminal

Isopleths ***Surface***

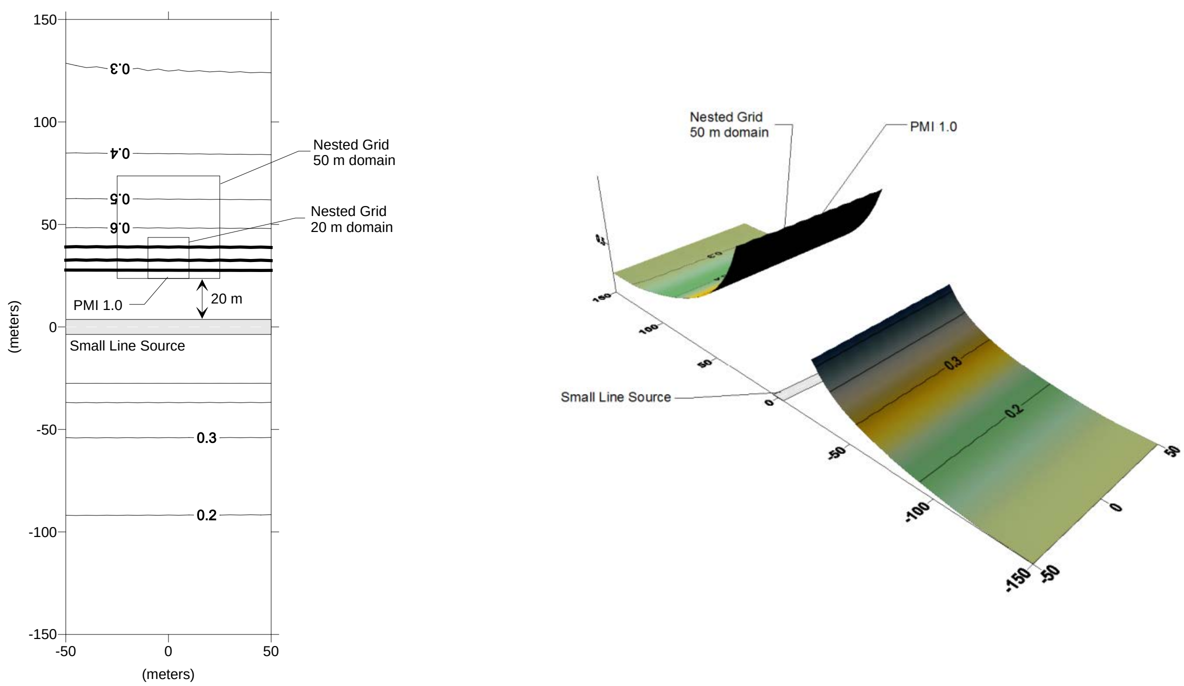
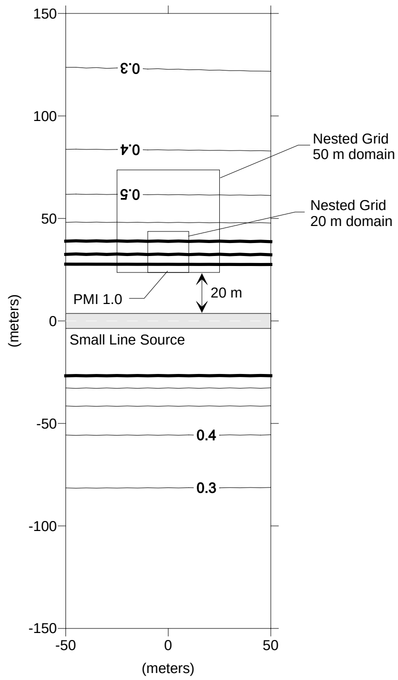


Figure AP C-3.11.3 – Small Line Source, CALINE – Kearny Mesa

Isopleths ***Surface***



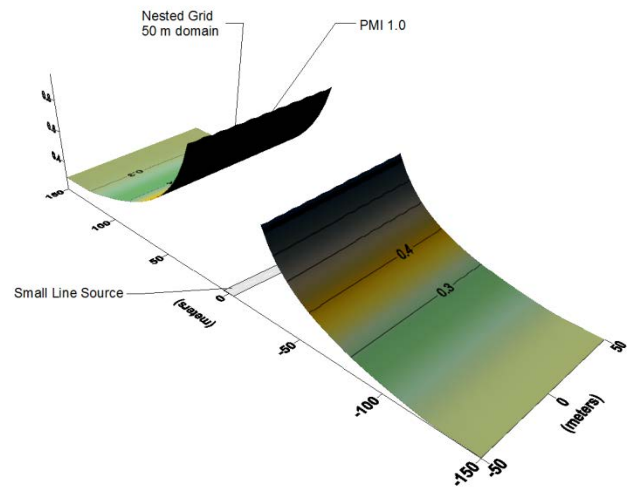
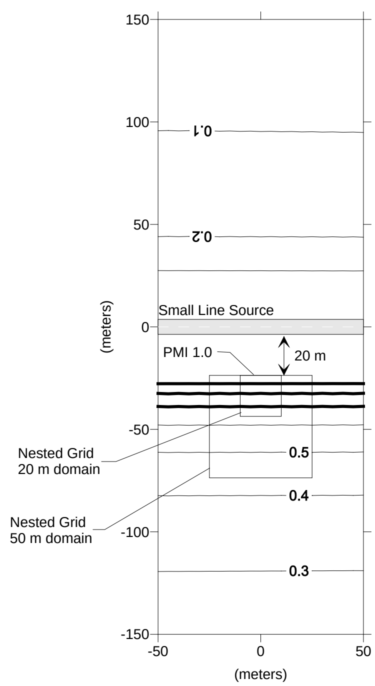


Figure AP C-3.11.4 – Small Line Source, CALINE – Lynwood

Isopleths ***Surface***



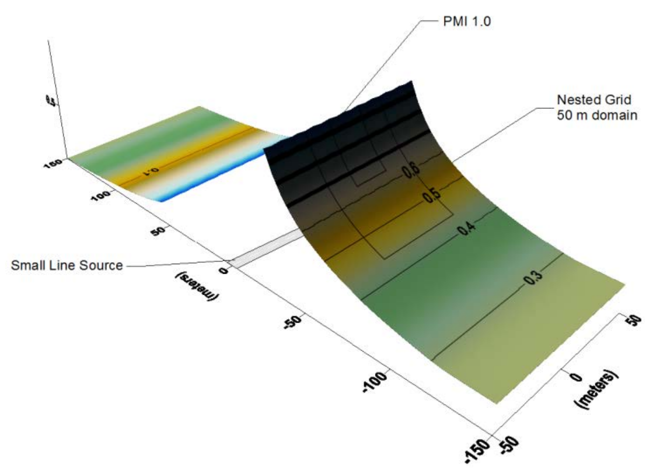
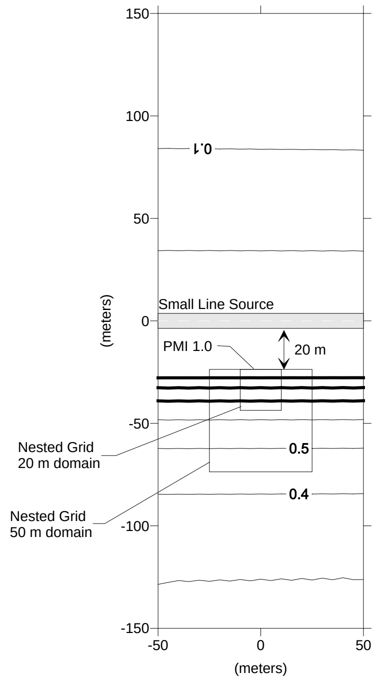
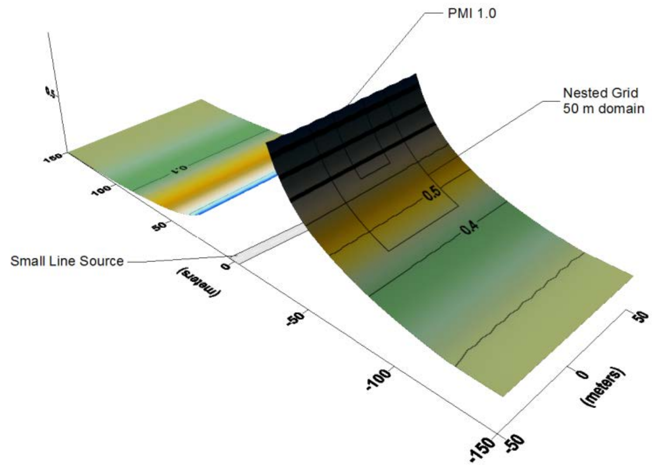


Figure AP C-3.11.5 – Small Line Source, CALINE – San Bernardino

Isopleths ***Surface***





Appendix C-4 – Spatial Average Tables

Table AP **C-**4.1.1 – Spatial Average – Point Source, Large

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.000	1.000	1.000	1.000	1.000
10x10	0.999	0.999	0.999	0.999	0.999
20x20	0.998	0.998	0.997	0.996	0.996
30x30	0.997	0.996	0.994	0.993	0.993
40x40	0.994	0.993	0.990	0.989	0.990
50x50	0.992	0.990	0.985	0.984	0.985
60x60	0.989	0.986	0.979	0.978	0.980
70x70	0.985	0.981	0.972	0.972	0.973
80x80	0.981	0.976	0.965	0.965	0.967
90x90	0.976	0.970	0.956	0.957	0.959
100x100	0.971	0.964	0.947	0.949	0.951

Table AP **C-**4.1.2 – Spatial Average – Point Source, Medium

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	1.00	0.99	0.99	0.99	0.99
20x20	0.99	0.98	0.98	0.98	0.98
30x30	0.98	0.97	0.97	0.97	0.97
40x40	0.97	0.95	0.94	0.95	0.95
50x50	0.95	0.92	0.92	0.92	0.93
60x60	0.93	0.89	0.89	0.89	0.90
70x70	0.91	0.86	0.86	0.86	0.87
80x80	0.89	0.83	0.82	0.83	0.84
90x90	0.87	0.79	0.79	0.80	0.81
100x100	0.84	0.76	0.76	0.76	0.78

Table AP **C-**4.1.3 – Spatial Average – Point Source, Small

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	1.01	0.70	0.83	0.83	0.84
20x20	0.85	0.56	0.69	0.68	0.69
30x30	0.73	0.44	0.58	0.58	0.57
40x40	0.63	0.36	0.50	0.49	0.48
50x50	0.55	0.30	0.44	0.43	0.41
60x60	0.49	0.25	0.39	0.40	0.36
70x70	0.44	0.22	0.34	0.37	0.32
80x80	0.39	0.19	0.31	0.33	0.28
90x90	0.36	0.17	0.28	0.27	0.26
100x100	0.32	0.15	0.25	0.24	0.23

Table AP **C-**4.2.1 – Spatial Average – Volume Source, Large

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.90	0.91	0.91	0.90	0.90
20x20	0.82	0.82	0.82	0.82	0.82
30x30	0.75	0.75	0.75	0.75	0.75
40x40	0.68	0.68	0.69	0.68	0.68
50x50	0.63	0.62	0.64	0.63	0.63
60x60	0.58	0.57	0.59	0.58	0.58
70x70	0.54	0.53	0.55	0.54	0.54
80x80	0.50	0.49	0.51	0.50	0.50
90x90	0.47	0.45	0.48	0.47	0.46
100x100	0.44	0.42	0.45	0.44	0.43

Table AP **C-**4.2.2 – Spatial Average – Volume Source, Medium

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.82	0.84	0.83	0.82	0.82
20x20	0.69	0.70	0.70	0.69	0.69
30x30	0.59	0.60	0.60	0.59	0.59
40x40	0.51	0.51	0.53	0.52	0.51
50x50	0.45	0.44	0.46	0.45	0.45
60x60	0.40	0.39	0.41	0.40	0.39
70x70	0.35	0.34	0.37	0.36	0.35
80x80	0.32	0.30	0.34	0.32	0.32
90x90	0.29	0.27	0.31	0.29	0.29
100x100	0.26	0.25	0.28	0.27	0.26

Table AP **C-**4.2.3 – Spatial Average – Volume Source, Small

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.76	0.76	0.76	0.76	0.75
20x20	0.60	0.60	0.61	0.60	0.59
30x30	0.49	0.47	0.50	0.49	0.48
40x40	0.41	0.39	0.42	0.41	0.40
50x50	0.35	0.32	0.36	0.35	0.34
60x60	0.30	0.27	0.32	0.30	0.29
70x70	0.26	0.24	0.28	0.26	0.25
80x80	0.23	0.21	0.25	0.23	0.22
90x90	0.20	0.18	0.22	0.20	0.20
100x100	0.18	0.16	0.20	0.18	0.18

Table AP **C-**4.3.1 – Spatial Average – Area Source, Large

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.90	0.95	0.93	0.93	0.93
20x20	0.83	0.89	0.87	0.86	0.87
30x30	0.76	0.85	0.82	0.81	0.81
40x40	0.71	0.80	0.78	0.76	0.77
50x50	0.66	0.77	0.74	0.72	0.73
60x60	0.62	0.73	0.70	0.69	0.69
70x70	0.59	0.70	0.67	0.66	0.66
80x80	0.56	0.67	0.64	0.63	0.64
90x90	0.53	0.64	0.62	0.60	0.61
100x100	0.51	0.62	0.59	0.58	0.59

Table AP **C-**4.3.2 – Spatial Average – Area Source, Medium

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1	1	1	1	1
10x10	0.88	0.94	0.91	0.91	0.91
20x20	0.78	0.87	0.83	0.82	0.83
30x30	0.69	0.81	0.76	0.75	0.76
40x40	0.63	0.75	0.70	0.69	0.70
50x50	0.57	0.69	0.65	0.64	0.65
60x60	0.53	0.65	0.61	0.60	0.61
70x70	0.49	0.60	0.57	0.56	0.57
80x80	0.45	0.56	0.54	0.52	0.53
90x90	0.42	0.53	0.50	0.49	0.50
100x100	0.39	0.49	0.47	0.46	0.47

Table AP **C-**4.3.3 – Spatial Average – Area Source, Small

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.64	0.65	0.65	0.65	0.65
20x20	0.44	0.44	0.46	0.46	0.45
30x30	0.32	0.32	0.34	0.26	0.33
40x40	0.25	0.24	0.26	0.21	0.25
50x50	0.20	0.19	0.21	0.17	0.20
60x60	0.16	0.16	0.17	0.14	0.16
70x70	0.13	0.13	0.14	0.14	0.14
80x80	0.11	0.11	0.12	0.12	0.12
90x90	0.10	0.10	0.11	0.10	0.10
100x100	0.09	0.08	0.09	0.09	0.09

Table AP **C-**4.4.1 – Spatial Average – Line Source, Large

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.93	0.93	0.93	0.93	0.93
20x20	0.87	0.88	0.88	0.87	0.88
30x30	0.83	0.83	0.83	0.83	0.83
40x40	0.78	0.79	0.79	0.79	0.79
50x50	0.75	0.75	0.75	0.75	0.75
60x60	0.72	0.72	0.72	0.72	0.72
70x70	0.69	0.70	0.69	0.69	0.70
80x80	0.66	0.67	0.67	0.66	0.67
90x90	0.64	0.65	0.64	0.64	0.65
100x100	0.62	0.63	0.62	0.62	0.63

Table AP **C-**4.4.2 – Spatial Average – Line Source, Small

Domain	CMSA	FAT	KMSA	Lynn	SBO
PMI	1.00	1.00	1.00	1.00	1.00
10x10	0.88	0.88	0.88	0.88	0.88
20x20	0.80	0.80	0.79	0.80	0.80
30x30	0.73	0.74	0.73	0.73	0.73
40x40	0.68	0.69	0.67	0.68	0.68
50x50	0.64	0.64	0.63	0.64	0.64
60x60	0.60	0.61	0.59	0.60	0.61
70x70	0.57	0.58	0.56	0.57	0.58
80x80	0.54	0.55	0.54	0.54	0.55
90x90	0.52	0.53	0.51	0.52	0.53
100x100	0.50	0.51	0.49	0.50	0.51

Appendix C-5 – Tilted Spatial Averaging

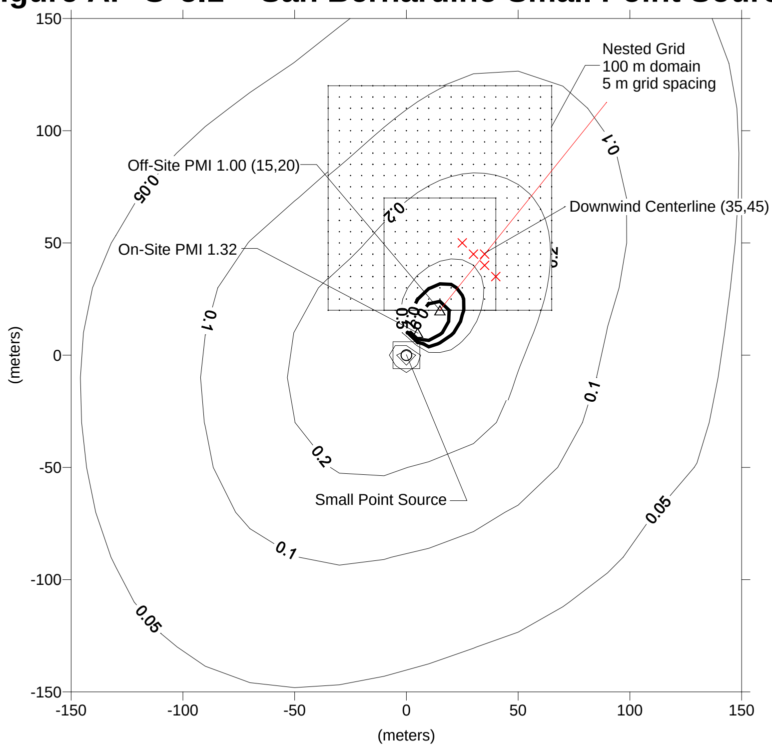
Tilted Spatial Averaging

Small sources tend to show an offsite PMI located at the fence line. It may be necessary to tilt the spatial averaging receptor field when the predominate wind direction carries the average plume centerline askew from the cardinal directions.

The first step in tilting the receptor field is to determine the centerline of the tilted receptor field. The centerline intersects the offsite PMI in the near field. We recommend locating the far end of the centerline by selecting receptors from the 5m spaced grid with the highest concentrations located approximately 30 meters from the offsite PMI.

For example, in the case of San Bernardino meteorology and a small point source, the offsite PMI is located at (15, 20). The dominat plume centerline can be determined from the existing set of receptors spaced at a 5 m grid cell resolution. The maximum concentration located approximately 30 meters from the offsite PMI can be used for the centerline. In this case the plume centerline was determined by plotting the receptors with the five highest concentrations and making a subjective selection of the centerline receptor at (35, 45). See red "x" receptors in Figure AP C-5.1.

Figure AP C-5.1 – San Bernardino Small Point Source



Polar coordinates can be easily calculated from the two points, (15, 20) and (35, 45), with basic trigonometry. In this case, dy/dx = 1.250, and the centerline tilted angle is 38.660 degrees from vertical (51.340 degrees from horizontal).

$$\tan\theta = \frac{dy}{dx} = \frac{45-20}{35-15} = \frac{25}{20} = 1.250$$

Therefore, $\theta = 38.660°$

We recommend that the polar receptor field cover half of a circular area, a 180 degree arc. So for our example the polar receptors centered on 38.660 degrees will sweep an arc from 308.660 degrees to 128.660 degrees (i.e., 38.660º ± 90º).

Polar receptors in AERMOD are easy to specify. Receptors should be placed on radials incremented every five meters. The polar angle of the radials should be placed to closely represent 5 meter grid spacing. For example, Table AP C-5.1 below shows the angular increment of radials for receptor placement out to 25m from the offsite PMI.

Table AP C-5.1 – Recommended Spacing for Tilted Polar Nested Grid

Radial Distance from PMI	0m	5m	10m	15m	20m	25m
Angle Increment (deg)	PMI	60.000	30.000	18.000	13.846	11.250
Resultant spacing along arc	PMI	5.24m	5.24m	4.71m	4.83m	4.91m

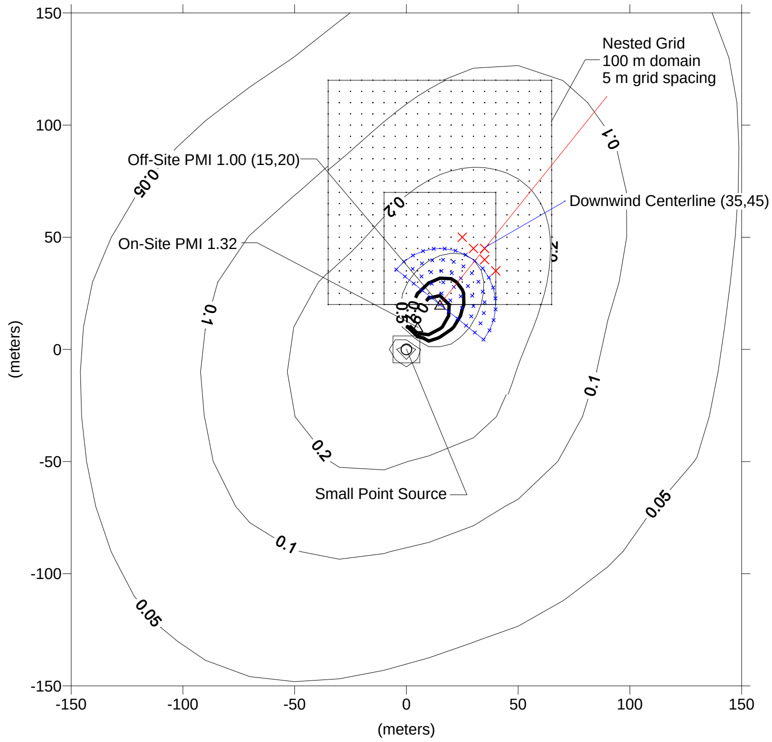
As a result of the above receptor spacing, the following field of polar receptors in Table AP **C-5.2** is needed for the San Bernardino example.

Table AP C-5.2 – Tilted Nested Grid for San Bernardino Example

Radial Distance →	5m	10m	15m	20m	25m
Radial Direction (degrees)					
1	308.660	308.660	308.660	308.660	308.660
2	8.660	338.660	326.660	322.506	319.910
3	68.660	8.660	344.660	336.352	331.160
4	128.660	38.660	2.660	350.198	342.410
5	-	68.660	20.660	4.044	353.660
6	-	98.660	38.660	17.891	4.910
7	-	128.660	56.660	31.737	16.160
8	-	-	74.660	45.583	27.410
9	-	-	92.660	59.429	38.660
10	-	-	110.660	73.275	49.910
11	-	-	128.660	87.121	61.160
12	-	-	-	100.968	72.410
13	-	-	-	114.814	83.660
14	-	-	-	128.660	94.910
15	-	-	-	-	106.160
16	-	-	-	-	117.410
17	-	-	-	-	128.660
Note: Be sure to include the offsite PMI in the polar spatial average.					

Figure AP **C-5.2** shows the resulting receptors for the above field as blue “x”s.

Figure AP C-5.2 – Tilted Nested Polar Grid for San Bernardino Point – Small



As an alternative, a rectangular tilted receptor field can also be created as shown in Figure **AP C-5.3**, below. The tilted rectangular field shown below requires more calculations than the tilted polar field above because discrete receptors must be generated outside of AERMOD. We recommend the tilted polar field approach because of the simplicity of inputting polar receptors into AERMOD.

Table AP C-5.3.1shows a summary of the spatial averaging of tilted nested grids for the San Bernardino meteorological data. In this example, there is little difference between the regular rectangular grid and the tilted rectangular grid.

Figures AP C-5.3.2 and E3.3 show the tilted grids for the volume and area sources examples. In these cases, the tilted grid spatial average is higher than the non-tilted grid. Table APC 5.3.2 shows the spatial average increases from 0.59 to 0.69 for the 20m x 20m nested grid.

Figures APC 5.4.1- APC 5.4.3 show similar trends for nested grids, in this case with meteorological data from the Fresno Air Terminal.

Figure AP C-5.3.1 – Tilted Nested Rectangular Grid for San Bernardino Point – Small

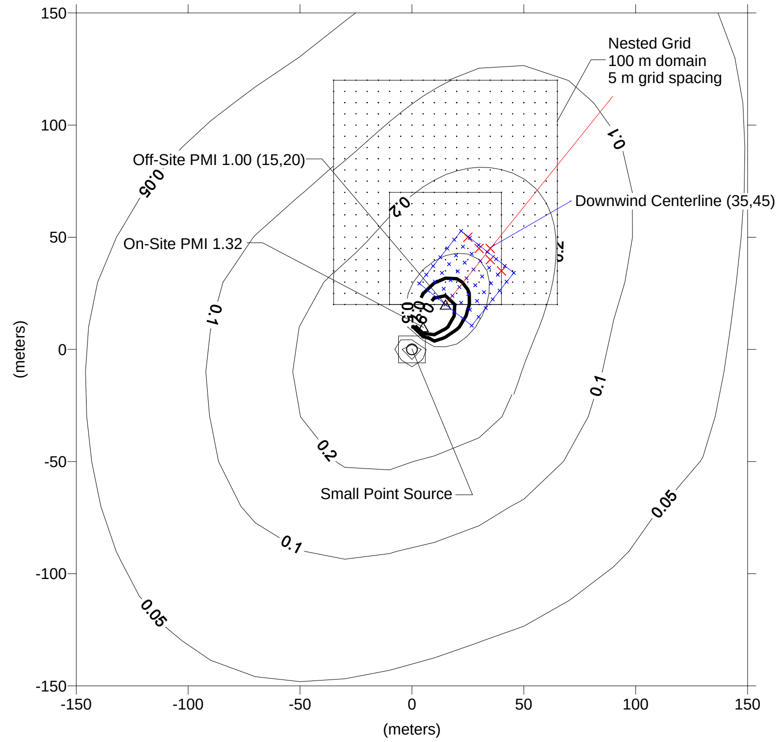


Table AP C-5.3.1 – Spatial Average – San Bernardino – Small Point Source

Nested Grid Domain in m^2	Cartesian Rectangular	Tilted Rectangular	Tilted Polar	Notes
0	1	1	1	PMI
39	-	-	0.91	Polar, R = 5m
100	0.84	0.84	-	Rectangular, 10m x 10m
157	-	-	0.81	Polar, R = 10m
353	-	-	0.71	Polar, R = 15m
400	0.69	0.68	-	Rectangular, 20m x 20m
628	-	-	0.63	Polar, R = 20m
900	0.57	0.58	-	Rectangular, 30m x 30m
982	-	-	0.56	Polar, R = 25m

Figure AP C-5.3.2 – Tilted Nested Grid for San Bernardino Volume – Small

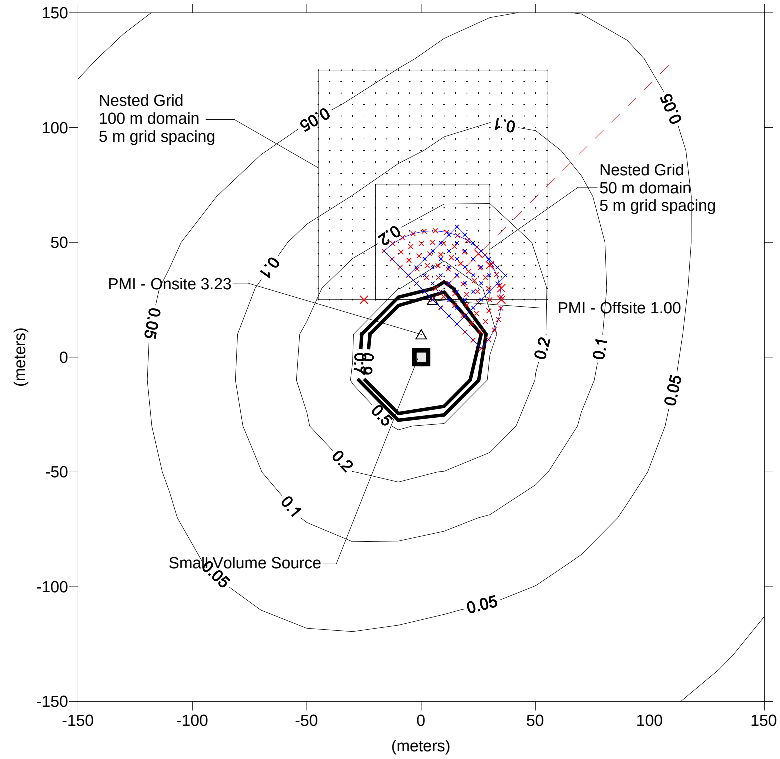


Table AP C-5.3.2 – Spatial Average – San Bernardino – Small Volume Source

Nested Grid Domain in m^2	Cartesian Rectangular	Tilted Rectangular	Tilted Polar	Notes
0	1	1	1	PMI
39	-	-	0.94	Polar, R = 5m
100	0.75	0.83	-	Rectangular, 10m x 10m
157	-	-	0.86	Polar, R = 10m
353	-	-	0.77	Polar, R = 15m
400	0.59	0.69	-	Rectangular, 20m x 20m
628	-	-	0.68	Polar, R = 20m
900	0.48	0.57	-	Rectangular, 30m x 30m
982	-	-	0.56	Polar, R = 25m

Figure AP C-5.3.3 – Tilted Nested Grid for San Bernardino Area – Small

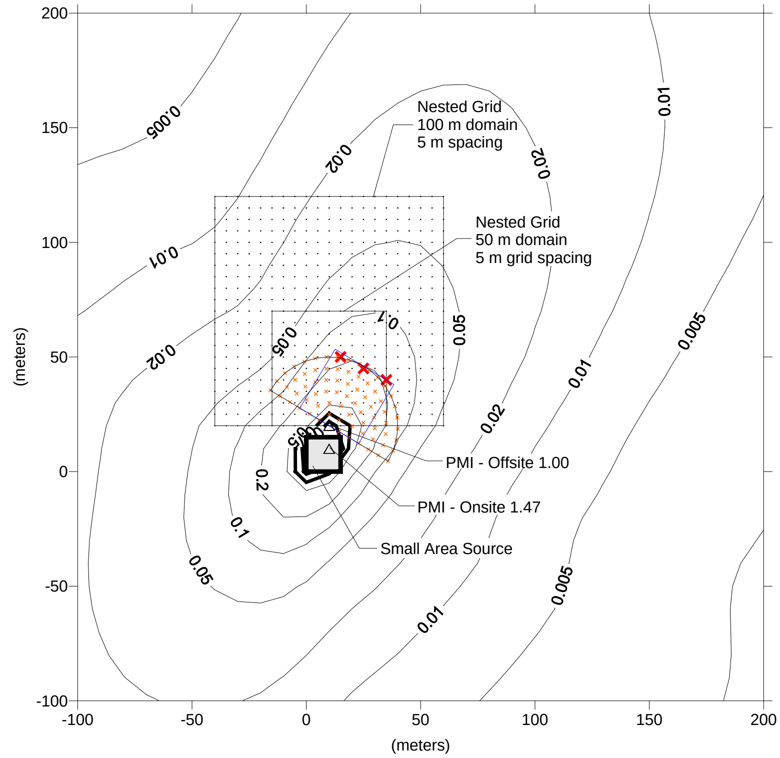


Table AP C-5.3.3 – Spatial Average – San Bernardino – Small Area Source

Nested Grid Domain in m^2	Cartesian Rectangular	Tilted Rectangular	Tilted Polar	Notes
0	1	1	1	PMI
39	-	-	0.86	Polar, R = 5m
100	0.65	0.71	-	Rectangular, 10m x 10m
157	-	-	0.68	Polar, R = 10m
353	-	-	0.52	Polar, R = 15m
400	0.45	0.50	-	Rectangular, 20m x 20m
628	-	-	0.42	Polar, R = 20m
900	0.33	0.36	-	Rectangular, 30m x 30m
982	-	-	0.34	Polar, R = 25m

Figure AP C-5.4.1 – Tilted Nested Rectangular Grid for Fresno Air Terminal Point – Small

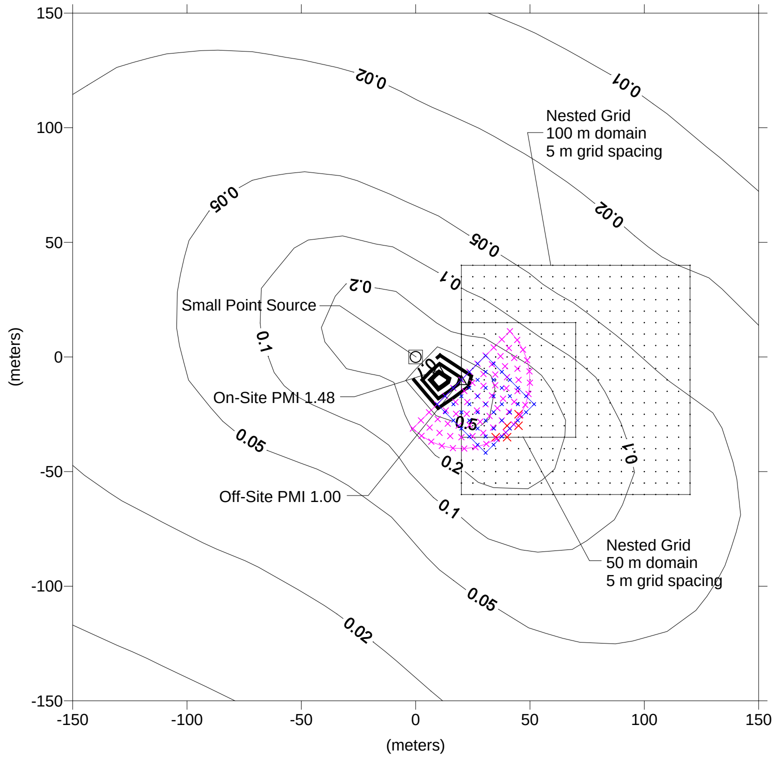


Table AP C-5.4.1 – Spatial Average – Fresno Air Terminal – Small Point Source

Nested Grid Domain in m^2	Cartesian Rectangular	Tilted Rectangular	Tilted Polar	Notes
0	1	1	1	PMI
39	-	-	0.92	Polar, R = 5m
100	0.70	0.83	-	Rectangular, 10m x 10m
157	-	-	0.79	Polar, R = 10m
353	-	-	0.67	Polar, R = 15m
400	0.56	0.67	-	Rectangular, 20m x 20m
628	-	-	0.58	Polar, R = 20m
900	0.44	0.54	-	Rectangular, 30m x 30m
982	-	-	0.50	Polar, R = 25m

Figure AP C-5.4.2 – Tilted Nested Rectangular Grid for Fresno Air Terminal Volume – Small

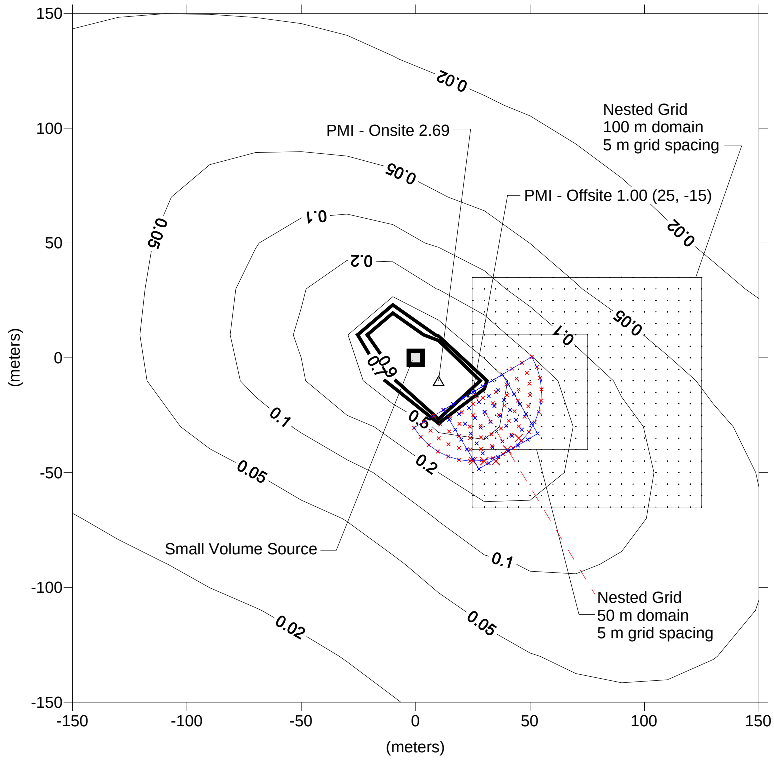


Table AP C-54.2 – Spatial Average – Fresno Air Terminal – Small Volume Source

Nested Grid Domain in m^2	Cartesian Rectangular	Tilted Rectangular	Tilted Polar	Notes
0	1	1	1	PMI
39	-	-	0.93	Polar, R = 5m
100	0.76	0.82	-	Rectangular, 10m x 10m
157	-	-	0.83	Polar, R = 10m
353	-	-	0.73	Polar, R = 15m
400	0.60	0.67	-	Rectangular, 20m x 20m
628	-	-	0.63	Polar, R = 20m
900	0.47	0.55	-	Rectangular, 30m x 30m
982	-	-	0.55	Polar, R = 25m

Figure AP C-5.4.3 – Tilted Nested Rectangular Grid for Fresno Air Terminal Area – Small

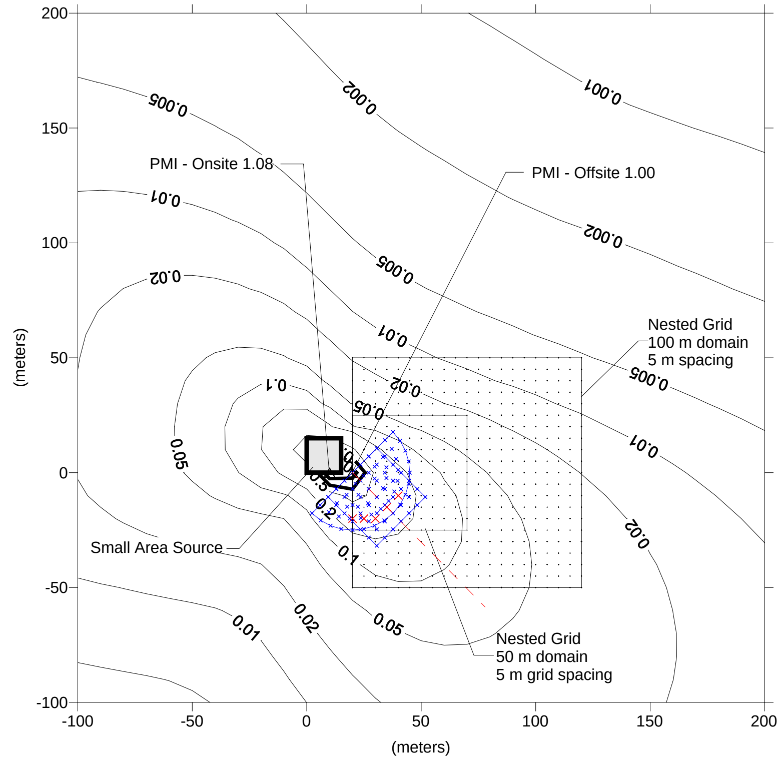


Table AP C-5.4.3 – Spatial Average – Fresno Air Terminal – Small Area Source

Nested Grid Domain in m^2	Cartesian Rectangular	Tilted Rectangular	Tilted Polar	Notes
0	1	1	1	PMI
39	-	-	0.83	Polar, R = 5m
100	0.65	0.69	-	Rectangular, 10m x 10m
157	-	-	0.65	Polar, R = 10m
353	-	-	0.51	Polar, R = 15m
400	0.44	0.49	-	Rectangular, 20m x 20m
628	-	-	0.41	Polar, R = 20m
900	0.32	0.37	-	Rectangular, 30m x 30m
982	-	-	0.34	Polar, R = 25m